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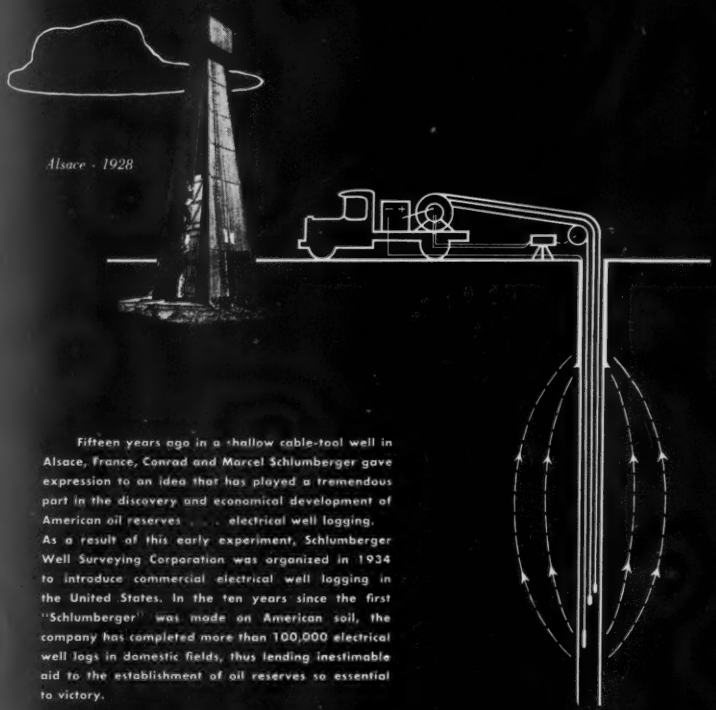

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By Lewis B. Kellum

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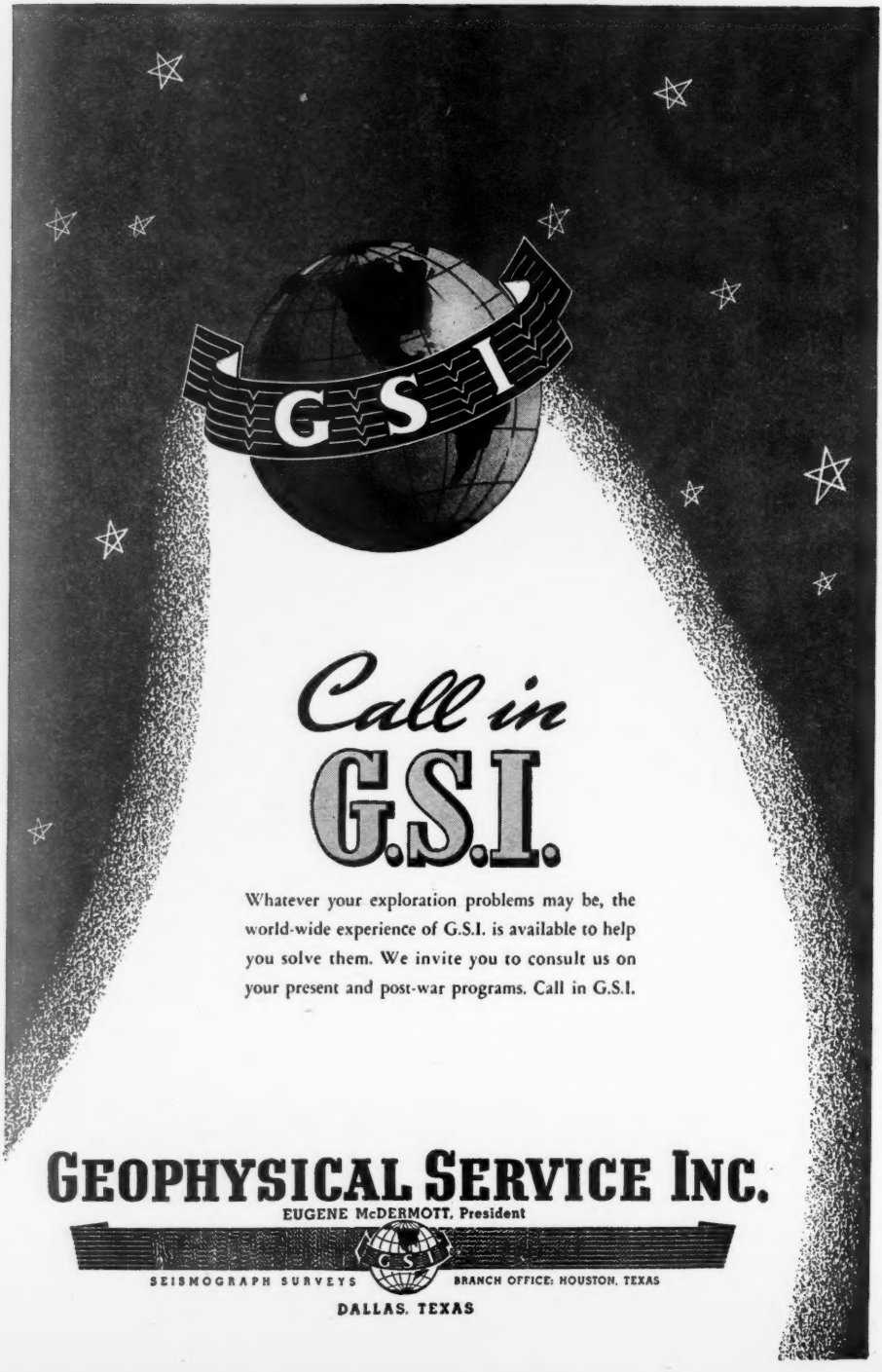
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Volume 28 Number 2

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of the
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FEBRUARY, 1944

PORTER OIL FIELD, MIDLAND COUNTY, MICHIGAN[1]

KENNETH K. LANDES[2]
Ann Arbor, Michigan

ABSTRACT

The Porter oil field is in southwestern Midland County, close to the center of the Southern Peninsula of Michigan. It was discovered in November, 1931, and since that time has produced more than 39 million barrels of oil. Porter leads all other Michigan fields in total production and in recovery per acre.

All of the oil produced is from Devonian formations; an insignificant percentage of the total production from the Traverse and the balance from Dundee limestone. Accumulation is in the Porter anticline, which is 9 miles long and three miles wide, with a closure of about 50 feet. The productivity of different wells on the anticline varies generally with the percentage of secondary porosity in the uppermost Dundee. This porosity developed mostly during a mid-Devonian emergence.

Deeper drilling in the Porter field to test older formations now productive elsewhere in the Michigan basin is considered desirable.

INTRODUCTION

The Porter oil field leads all Michigan fields in total production and in recovery per acre. Now, 11 years after discovery, it ranks fourth among Michigan fields in daily production. The only detailed description, heretofore, was in an unpublished master's thesis.[3]

The Porter field (Fig. 1) is in southwestern Midland County. At the north and northwest, across a 3-mile-wide area dotted with dry holes, is the Greendale or Mount Pleasant field. Farther northwest, in Isabella, Clare, and southwestern Missaukee counties, are other oil and gas fields on the same general trend, including the well known pools of Vernon, Freeman, Redding, and Winterfield. The greater part of the total Michigan oil produced to date has come from this trend. No fields on this line of folding have been discovered southeast of Porter.

The Yost-Jasper field occupies the northwest end of the Porter anticline. It was listed as a separate field from the Porter at the time of its discovery and is still carried separately in the production statistics. But the Yost-Jasper and the Porter fields are both a part of the same subsurface pool, and in this report the Porter field is defined as including the Yost-Jasper.

[1] Presented by title before the Association at Fort Worth, April 7–9, 1943. Manuscript received, June 15, 1943.

[2] Chairman, department of geology, University of Michigan.

[3] Jed. B. Maebius, "Porter Oil Field," Department of Geology, University of Michigan, May, 1935.

FIG. 1.—Map of Michigan oil fields, with position of Porter field indicated by circle.

The Porter field covers the central part of T. 13 N., R. 1 W. (Midland Township), and extends northwest across the northeast corner of T. 13 N., R. 2 W. (Jasper Township), into the southern halves of Secs. 34 and 35, T. 14 N., R. 2 W. (Greendale Township).

HISTORY

As the bedrock in the Midland-Isabella-Clare region is buried under several hundred feet of glacial drift, structures favorable to the accumulation of oil can not be discovered by surface geological studies. Fortunately, in the area are many brine wells drilled by the Dow Chemical Company of Midland, Michigan. The records of these wells were examined in 1926 by Thomas C. Hiestand, then of the Pure Oil Company, and the anticlinal trend on which the Porter, Mount Pleasant, Vernon, and other fields were subsequently discovered was recognized. On the basis of this work a large area was leased by the Pure Oil Company, followed by other companies. In 1928 the Pure Oil Company tested the best part of the structure, as mapped by Hiestand, and the discovery of the Mount Pleasant field resulted. The Leaton and Vernon pools, on the northwest, were discovered in 1929 and 1930, respectively.

Porter was the fourth pool discovered as a result of testing the anticlinal trend recognized from brine-well records. The first test, however, was a failure, but subsequent development proved it to be only one location north of the pool. This well, drilled in the NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 8, T. 13 N., R. 1 W., in the early months of 1930, had a very encouraging showing of oil. The first commercial producer was $1\frac{1}{2}$ years later (November 14, 1931),—the Michigan Pacific Oil and Gas Company's James Otway, Jr., NW. corner of Sec. 26, T. 13 N., R. 1 W. The Pure Oil Company participated in financing this test. It flowed, with swabbing, 118 barrels the first day. Subsequently, the well was shot and it settled to a daily production of 40 barrels. An offset on the north, completed the following February, was dry and interest in the area waned.

The next event in the history of the Porter field was the completion of a well with an initial daily production of 676 barrels, the Pure Oil Company's Mattie Yost, which gave the Yost field its name, in the S. $\frac{1}{2}$, W. $\frac{1}{2}$, W. $\frac{1}{2}$ of Sec. 35, T. 14 N., R. 2 W. (Greendale Township). Development in the vicinity was rapid, and at the same time interest in the possibilities of Porter township were reawakened. As a result, Teater and Kirkham's J. H. Otway well No. 1 was drilled in the NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 22, T. 13 N., R. 1 W. This well had an initial production of 400 barrels per day, but after being drilled 35 feet deeper and treated with acid, its flow increased to 3,200 barrels in 36 hours. Then followed a drilling boom in Porter Township. During the subsequent development, successful wells were drilled between the Yost and the Otway wells, including a number in the northeast part of Jasper Township (T. 13 N., R. 2 W.), and the Yost and Porter fields became merged. Altogether, 419 producers have been drilled in this area.

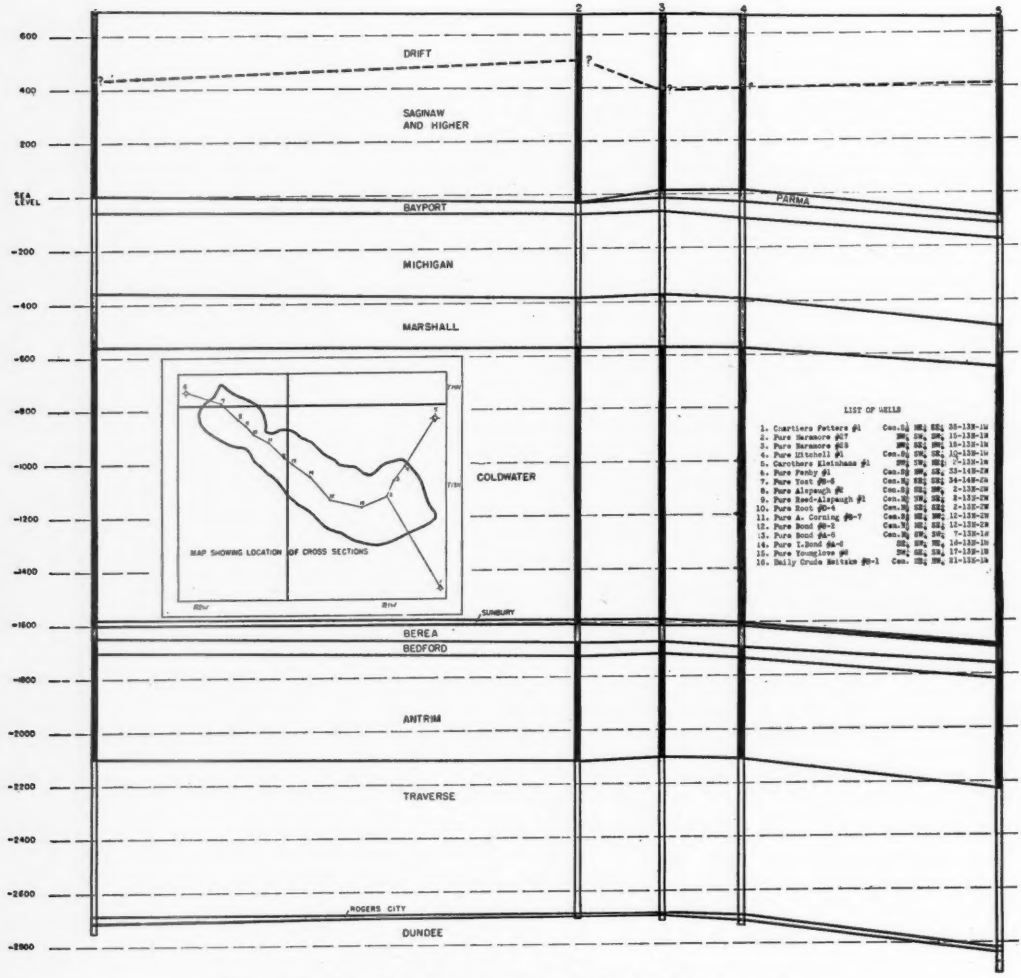

FIG. 2.—South-north section across east end of Porter field. Inserts show location of sections and list of wells.

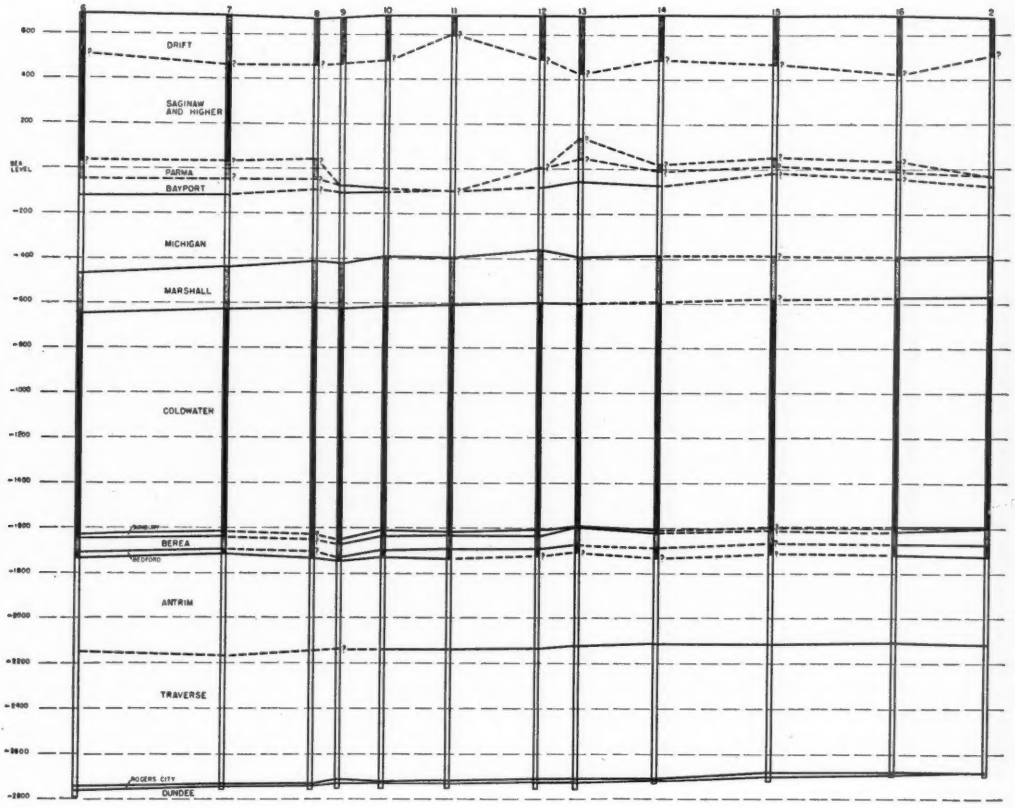

FIG. 3.—West-east section through Porter field.

REGIONAL AND LOCAL GEOLOGY

The Porter field lies in the Saginaw River drainage basin which was the lake bottom of glacial Lake Saginaw during the latter part of the glacial period. Beneath the lake clays and sands is Pennsylvanian bedrock. Southwestern Midland County is near the center of the roughly circular area in which Pennsylvanian rocks are at the top of the bedrock series.

As no bedrock exposures occur in or close to the Porter field, all geologic mapping has to be done from well information. Because it was the floor of a lake in the relatively recent past, the topography in the Porter region is flat. The area is drained by Pine River, which flows northeasterly across the field in a valley only slightly below the lake plain surface. The cross sections (Figs. 2 and 3) show the surface relief is very slight. The relief on the bedrock surface is much more pronounced.

STRATIGRAPHY

Samples of cuttings were available for this study from 29 wells drilled in and near the Porter field. Few of these sets of cuttings were complete, however. The procedure in studying the stratigraphy was first to glue the samples from each well on thin cardboard log strips ruled at a scale of 20 feet to the inch. Then the cuttings were examined with binocular microscope by sliding the strips beneath the objectives. Dolomite determinations were made by acid reaction and checked by staining or sink-float test in a heavy liquid.

DUNDEE AND ROGERS CITY FORMATIONS

The Rogers City limestone formation was separated from the top of the Dundee formation by Ehlers and Radabaugh[4] on paleontologic evidence obtained in the Rogers City quarry near Lake Huron in Presque Isle County. The first published recognition of the Rogers City limestone in a subsurface section was made by Addison[5] in his report on the Buckeye field in Gladwin County. Addison differentiated the Rogers City from the underlying Dundee (restricted) on lithologic grounds. The same distinction can be made in the Porter field. So far, however, no paleontologic evidence has been obtained which definitely proves that the so-called Rogers City formation in the Buckeye and Porter fields is the same as the Rogers City formation at the outcrop.

The seas during Dundee and Rogers City time were limestone-depositing waters. However, the resulting Dundee formation in the Porter and Buckeye areas is yellow, tan, or buff limestone, whereas the overlying Rogers City is dark brown limestone with a resinous luster. The color change between the two formations is marked.

[4] George M. Ehlers and Robert E. Radabaugh, "The Rogers City Limestone, a New Middle Devonian Formation in Michigan," *Papers Michigan Acad. Sci., Arts and Letters*, Vol. 23 (1938), pp. 441–45.

[5] Carl C. Addison, "Buckeye Oil Field, Gladwin County, Michigan," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 11 (November, 1940), pp. 1961–64.

Differentiating the Rogers City from the Dundee in the subsurface section is of more than academic importance. The pay zone in the Porter area lies at the top of the Dundee formation immediately underlying the Rogers City.

FIG. 4.—Photomicrograph of Dundee limestone, showing secondary porosity. Magnification about 20×.

Dundee formation.—Because the pay zone is at the top of the Dundee, most wells cease drilling and penetrate only a few feet of the formation below this zone. The deepest well from which samples were studied is the Pure Oil Company's Root C-9 in Sec. 20, T. 13 N., R. 1 W., which penetrated 111 feet of Dundee before being abandoned as a dry hole. Samples were also examined from the Wicklund State A-1 well in Sec. 11, T. 18 N., R. 1 W. in the North Buckeye pool which penetrated the Dundee and into the upper Monroe. According to the

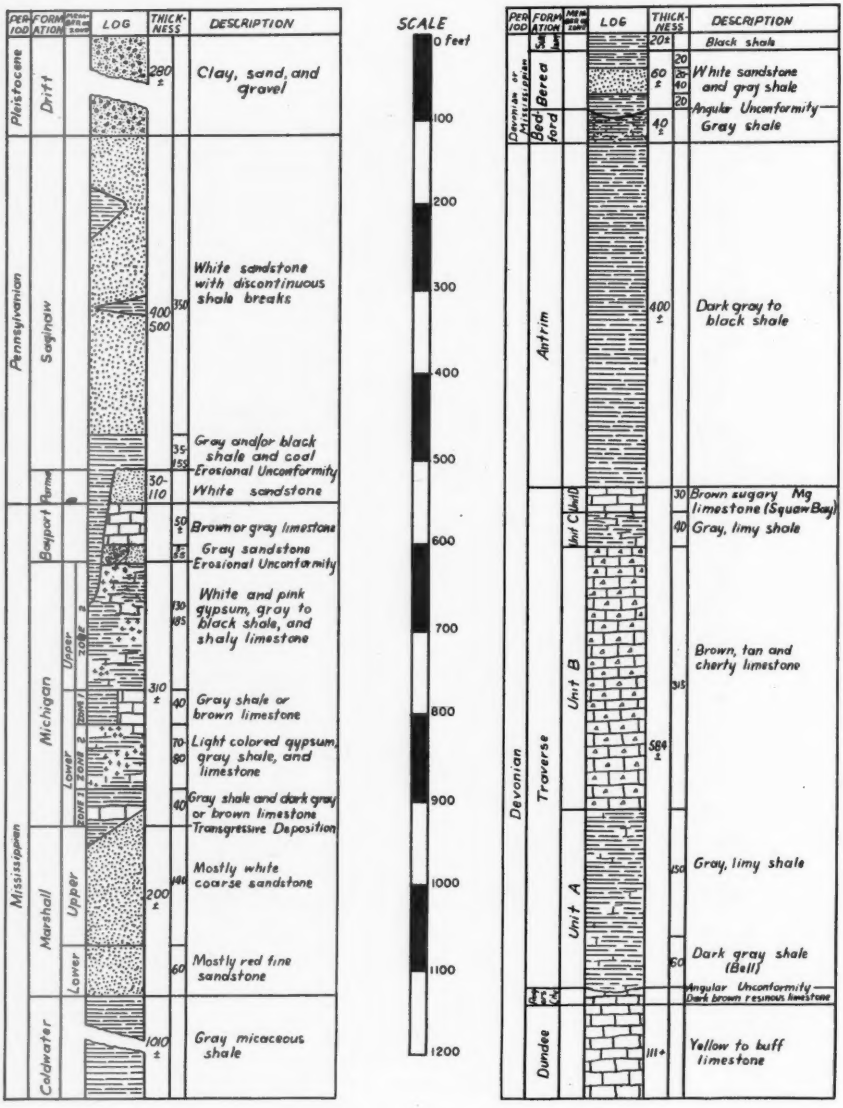

FIG. 5.—Generalized columnar section for Porter field.

writer's designation of the Monroe-Dundee boundary, this well passed through a section of the Dundee 268 feet in thickness.

The color of the Dundee limestone ranges from light yellow or tan to buff. Pyrite grains are present near the top. This limestone breaks down almost into a powder during drilling. In most of the wells, the cuttings from the top of the Dundee contain solution cavities (Fig. 4) lined with a film of oil. The thickness of this porous zone is variable. Its significance is discussed in the section on "Accumulation of Oil."

Rogers City formation.—The minimum thickness of the Rogers City formation in the 29 wells of the Porter area from which cuttings were available is 4 feet. This abnormally thin section is in a well in the NW. ¼, SW. ¼, SW. ¼ of Sec. 15, T. 13 N., R. 1 W., near the highest point on the Porter anticline. The maximum thickness, 35 feet, is in a dry hole southeast of the Porter field in the S. ½, NE. ¼, SE. ¼ of Sec. 35, T. 13 N., R. 1 W. The range in thickness on the anticline is 4 to 19 feet, except in a dry hole in the NW. ¼, NW. ¼ of Sec. 20, T. 13 N., R. 1 W., where the thickness is 26 feet; off the anticline the range is from 19 to 35 feet.

The distribution of Rogers City thicknesses is highly suggestive of a pre-Traverse emergence with minor folding along the Porter anticline and some erosion of the Rogers City formation, especially in the area undergoing uplift. Newcombe[6] discusses other evidence for an unconformity at the base of the Traverse. The unconformity in the quarry at Calcite, Presque Isle County, has been described by Radabaugh[7] and Warthin and Cooper.[8]

As previously stated, the Rogers City formation in the Porter field is dark brown limestone with a resinous to sugary luster. As a general rule it grinds into much coarser fragments than does the underlying lighter-colored Dundee.

TRAVERSE LIMESTONE AND SHALE

When the seas came over the Porter area at the beginning of Traverse time, both fine clastic material and calcium carbonate were deposited. After this early phase the waters became clearer and a thick deposit of limestone was laid down. This was succeeded by a second period of mixed shale and limestone deposition, followed by deposition of limestone again. During this last phase, some magnesium salts were present in the seas and were deposited with the calcium carbonate. As a result of this cyclical deposition, the Traverse in the subsurface section consists of an alternating series of calcareous shale (or shaly limestone) and limestone (Fig. 5).

The thickness of the Traverse in the Porter area ranges from 568 to 597 feet; the average thickness, in the fourteen wells for which samples were available, is

[6] R. B. Newcombe, "Middle Devonian Unconformity in Michigan," *Bull. Geol. Soc. America*, Vol. 41 (1930), pp. 725–38.

[7] Robert E. Radabaugh, "Stratigraphy and Paleontology of Middle Devonian Rogers City Limestone of Michigan," Ph. D. thesis, University of Michigan, 1942.

[8] Aldred S. Warthin, Jr., and G. Arthur Cooper, "Traverse Rocks of Thunder Bay Region, Michigan," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 5 (May, 1942), p. 580.

584 feet. This is 160 feet thinner than the same section in the North Buckeye pool, 30 miles north. The general thickening of the Traverse toward the northeast indicates that deposition was increased in the area of greatest basinward downwarping and the source of the sediments probably was in that direction.

The subsurface section of the Porter area contains four distinct divisions of the Traverse in contrast to six divisions in the Buckeye area,[9,10] and eleven in the Thunder Bay outcrop area near Alpena.[11] The top three divisions are the same in both areas, but as the lower three of Hake and Maebius are not readily separable at Porter, they are grouped together in this report.

The basal division in the Porter Traverse section, corresponding with units 1 to 3 of Hake and Maebius, composes 35 per cent of the entire section. It consists throughout of gray shaly rock. This division is here called Unit A. Above Unit A is Unit B which is the largest of the four, comprising about 53 per cent of the section. It consists of cherty limestone ranging in color from nearly white to very dark brown. Unit C, comprising 6 per cent of the section, is gray calcareous shale; and Unit D, approximately 5 per cent of the total, is brown limestone.

Unit A.—Unit A consists of the Bell shale (A1) and overlying gray shale and shaly limestone (A2). The former, where it can be recognized, has an average thickness of 60 feet. This is 10 feet less than the average thickness of the Bell shale in the Buckeye pool. Unit A2 is about 150 feet thick, whereas the correlative units (2 and 3) at Buckeye total more than 250 feet.

In the samples of the Pure Oil Company's I. Bond A6 in Sec. 18, T. 13 N., R. 1 W., the top of the Bell shale is marked by a distinct change in color from dark gray to light gray, accompanied by an increase in calcium carbonate content above this point. In other wells there is little or no color change between the Bell shale and the overlying rock. The approximate position of this contact was determined by noting where the calcareous content of the shale showed considerable increase. In none of the Porter samples examined was the "gray to white limestone," mentioned by Addision and placed by Hake and Maebius in their Unit 2 found above the Bell shale. However, a somewhat greater calcareous content was noted in the samples from the first 50 feet above the Bell shale. Addison[12] correlates this zone with his Unit 2 at Buckeye.

Samples collected at the outcrop of the Bell shale in the Rogers City quarry are lighter in color and more calcareous than the shale of Unit A1, but as both of these shales overlie the Rogers City limestone, their correlation is probable. Unit A2, corresponding with units 2 and 3 of Hake and Maebius, is correlated by those authors with that part of the Traverse section extending from the Rockport to the Killians. These outcrop units are mainly limestones, excepting the lower

[9] Benjamin F. Hake and Jed Maebius, "Lithology of the Traverse Group of Central Michigan," *Papers Michigan Acad. Sci., Arts and Letters*, Vol. 23 (1937), pp. 447–61.

[10] Carl C. Addison, *op. cit.*, p. 1965.

[11] Warthin and Cooper, *op. cit.*, p. 579.

[12] Carl C. Addison, letter dated January 12, 1943.

Genshaw, which contains some beds of calcareous shale, and the upper part of the Ferron Point which, in the abandoned clay pit of Alpena Portland Cement Company in Sec. 18, T. 32 N., R. 9 E., Alpena County, contains more than 20 feet of greenish gray clay shale. The Killians limestone is recognized at the outcrop by its very dark, nearly black, color. It was noted that the shaly limestone at the top of Unit A in most of the Porter field samples is very dark in color and may, therefore, correspond with the Killians. It is obvious, however, that the lower Traverse section becomes more shaly between the outcrop and Midland County.

Unit B.—This unit has an average thickness of 315 feet in the Porter area and is the only one of the Traverse divisions that is thicker than its counterpart in the Buckeye field where, according to Addison,[13] the average thickness is 290 feet. Unit B is essentially a limestone unit, with much light-colored chert. The limestones at both the top and the bottom are brown in color so the contact between the overlying and underlying gray shaly material is marked. Between these brown limestones are cream- to tan-colored layers, and additional brown limestone beds. Shaly phases are thin and insignificant.

The Alpena limestone probably comprises a major part of this section. The uppermost part of Unit B may correspond with the Norway Point and Potter Farm members.

Unit C.—Unit C is, on the average, nearly 40 feet thick in the Porter field. This is only half the thickness reported for the corresponding unit (5) in the Buckeye pool. The thickness at Porter is exceptionally variable, extending from 18 to 55 feet in the samples examined. Unit C is consistently composed of gray calcareous shale and is readily differentiated from the underlying and overlying limestone units.

This unit has not been correlated with the outcrop section, perhaps because it is a shale and does not occur in natural outcrops. Another possible explanation is that it does correspond in time of deposition with upper Traverse beds, such as the Thunder Bay, but the sediments deposited out in the basin were much more argillaceous.

Unit D.—The uppermost unit of the Traverse section in the Porter field has an average thickness of about 30 feet, which is a little more than half the thickness of the same unit in the Buckeye area. Here also the range between extremes is nearly 50 per cent. The unit consists of brown sugary limestone, with dolomite at the very top of the section in six wells of fourteen examined. Dolomite was also observed near the top of the Squaw Bay (uppermost member of the Traverse in the outcrop section) at its type locality in Alpena County. From its position and lithologic character, Unit D is correlated with the Squaw Bay. This correlation was also made by Hake and Maebius for their corresponding unit 6. Unit D is the only Traverse division in the Porter section that can be correlated with any degree of certainty with the outcrop, other than the Bell shale whose upper limit is poorly defined.

[13] *Op. cit.*, p. 1965.

Oil in Traverse.—Several drillers' logs report "oil shows" in the Traverse, and at least one well was completed as a commercial producer in this part of the section. This well, Joseph Trevor's F. Forbes No. 1, SW. corner of Sec. 22, T. 13 N., R. 1 W., flowed 75 barrels per day initially from a depth 225 feet below the top of the Traverse. The stratigraphic position of the producing zone is approximately the middle of Unit B. Two wells from which samples were available reported showings of oil in the upper part of Unit B. In one of these, the Fetters No. 1, Sec. 35, T. 13 N., R. 1 W., the showing was reported 57 feet below the top, and in the other, the Kleinhans No. 1, Sec. 2 of the same township, the uppermost 12 feet of Unit B produced a showing of oil.

Addison[14] states that interested companies are now engaged in perforating the casing of wells in which good Traverse showings were reported. When the time comes to abandon such a well as a Dundee producer, the Traverse showing is tested by gun perforating at the proper level. To date five wells have been treated in this manner, and two of the five developed commercial production in the Traverse.

ANTRIM FORMATION

The Antrim shale formation in the Porter district has an average thickness of 397 feet. The formation is 46 feet thinner on the west than on the east end of the Porter field. This is in accord with the regional convergence described by Tarbell.[15]

Addison reported an average thickness for the formation in the Buckeye area of 425 feet, and one of the wells in that field, the B. Oard No. 1, Sec. 25, T. 18 N., R. 1 W., yielded 476 feet of Antrim cuttings.

The Antrim shale cuttings from the Porter wells are dark grayish black to jet black and, in the upper three-fourths of the section, entirely non-calcareous. A little calcium carbonate was apparently present in the early Antrim sea, but throughout the greater part of Antrim time only argillaceous material rich in finely divided plant débris was deposited.

In the basal 70–100 feet of the Antrim three zones can be differentiated in most wells. The lowest one extends from the base of the Antrim upward 25–40 feet. It is gray to black and calcareous, due to the presence of a small amount of limestone. Above is a black, non-calcareous zone made up of the same type of shale as occurs in the top 300 feet of section. This ranges in thickness from 15 to 30 feet. Overlying it is a second calcareous section which is grayer in color than the basal zone, as a general rule.

Pyrite is present in the Antrim, especially in the calcareous zones near the base.

The basal contact of the Antrim shale is exceptionally sharp. The contrast in both color and texture between the brown limestone of the Squaw Bay division

[14] Carl C. Addison, letter dated January 12, 1943.

[15] Eleanor Tarbell, "Antrim-Ellsworth-Coldwater Shale Formations in Michigan," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 4 (April, 1941), p. 727.

of the Traverse and the dark gray to black shale of the Antrim makes the distinction between the two units an easy one. In the Porter section there is only a trace of the lower Antrim limestones which make the determination of the Antrim and Traverse contact difficult elsewhere in the basin.

Until recently, it has seemed necessary to consider the lower part of the Antrim Devonian and the upper part Mississippian. It is now believed probable that the entire formation is Devonian.[16]

BEDFORD FORMATION

The Bedford formation does not crop out in Michigan. The name is imported from Bedford, Ohio, where beds somewhat similar to those found in Michigan wells consist of red and blue clay shale 50 feet thick which underlies the Berea grit. It has been pointed out by Cooper[17] that the Michigan Bedford, and the overlying Berea and Sunbury formations, were deposited in a separate basin from that in which the Ohio type formations were deposited. The dearth of fossils in the Michigan rocks has prevented definite correlation of the two sets of strata. For the same reason it is not possible to determine their age. In this report the Bedford, Berea, and Sunbury are classified as "Devonian or Mississippian."

Twenty-one sets of Bedford samples were examined during the preparation of this report. The average thickness for the formation is 40 feet, but the variation is considerable. The maximum thickness found is 62 feet, and the minimum is 13 feet. The isopach map of the Bedford formation shows a noticeable thinning along the west half of the axis of the Porter anticline. It is possible that this part of the anticline was moderately upfolded after Bedford deposition, and the strata bevelled during a subsequent period of erosion.

The Bedford formation in the Porter field consists entirely of a non-calcareous gray shale, except in 5 wells in which a small amount of shaly limestone was observed. The contact with the underlying Antrim is sharp, due to the wide divergence in color between light gray and nearly black shale. The conditions which supplied the organic débris during Antrim time obviously did not exist during the Bedford stage.

BEREA FORMATION

The name of the Berea formation is likewise taken from a locality in Cuyahoga County in northern Ohio. This formation underlies the glacial drift in parts of southern and northeastern Michigan, but has not been found exposed.

The Berea section in the Porter field ranges from 42 to 79 feet in thickness, with an average of 60 feet. This is 10–20 feet greater than the Berea section in the Buckeye pool.

The resubmergence of the Bedford surface beneath the Berea sea in the eastern part of Michigan resulted in the deposition of sand, especially in mid-Berea

[16] G. Arthur Cooper *et al.*, "Correlation of the Devonian Sedimentary Formations of North America," *Bull. Geol. Soc. America*, Vol. 53 (1942), pp. 1744–45.

[17] *Op. cit.*, p. 1757.

time. Shale, however, was also deposited on the floor of this sea. The three-fold division of the Berea sediments described by Baltrusaitis[18] can be recognized in many of the samples obtained from Porter wells. The top division, ordinarily about 20 feet thick, is mostly gray shale similar in appearance to that composing the Bedford formation. With the gray shale is a subordinate amount of sandstone. Pyrite may be fairly abundant. The middle zone ranges from 20 to 40 feet in thickness and is mostly white sandstone with a few fragments of gray shale. The white sandstone consists of rounded coarse grains cemented together with a dolomitic cement. The grains are very fine and the pounding of the bit during the drilling of the wells failed to separate the individual grains, so that sandstone fragments rather than sand grains make up the drill cuttings. The basal zone, about 20 feet in thickness, is a mixture of the same type of sandstone and shale found in the two upper zones. The base of the Berea and the top of the Bedford is determined by the disappearance of sandstone fragments.

The three-fold division of the Berea was not present in every well. In some wells the lowest zone was absent and the section consisted of an upper zone of shale with a little sandstone and a lower zone of sandstone with a little shale. In a few wells, sandstone was predominant throughout the section.

SUNBURY FORMATION

Following Berea sedimentation, a sequence similar to the Antrim-Bedford depositional cycle was repeated. Black Sunbury shale was deposited, followed by gray Coldwater shale. However, the volume relationship between the two shales was reversed, the Sunbury being thin and the Coldwater thick.

The Sunbury formation is also named after a locality in Ohio, and does not crop out in Michigan. It is black shale very similar in appearance to the deeper Antrim. The thickness in the Porter field ranges from 9 to 29 feet, with an average of 20 feet. The average thickness is only half the thickness reported by Addison[19] for the Buckeye Sunbury.

The Sunbury formation is very readily spotted in the well cuttings because of the contrast in color between it and the underlying gray shale of the upper Berea and the gray shale of the overlying Coldwater.

COLDWATER FORMATION

The Coldwater is the thickest formation in the section so far explored in the Porter district. The average thickness in 19 wells examined is 1,010 feet. The maximum range is from 964 to 1,038 feet.

The Coldwater consists mainly of gray micaceous shale. The micaceous character suggests that the streams entering the Coldwater area were draining a granitic terrane. Also abundant are fragments of gray to white arenaceous shale with calcareous cement. The shale grades into fine-grained sandstones similar in ap-

[18] E. J. Baltrusaitis, paper read before the Michigan Academy of Science, April, 1942.

[19] *Op. cit.*, p. 1966.

pearance to the Berea. Scattered throughout the section are grains of pink dolomitic shale. A rusty sandstone, similar to the lower Marshall, occurs about 70 feet below the top of the formation in some of the wells; however, a search failed to find any horizon markers which were continuous throughout the field.

The Coldwater formation, with its dominant gray color, makes a strong contrast with the underlying jet black Sunbury and the overlying dark red lower Marshall.

The relationship between the Coldwater and the lower shales in parts of the Michigan basin has been discussed by Tarbell[20] and Hale.[21]

MARSHALL FORMATION

The Marshall overlies the Coldwater shale and consists of white and red sandstone. The average thickness in this area is 200 feet, with maximum range from 157 to 238 feet.

It has been the custom in subsurface studies to divide the Marshall formation into upper Marshall or Napoleon, and the lower Marshall or "Red-Rock." In the Porter field the lower red series ranges from 67 to 119 feet in thickness, with an average of 87 feet. The overlying Napoleon has even greater range, extending from 76 to 167 feet, with an average of 115 feet. The variation in thickness of the entire Marshall is not as great as that of its two members. Furthermore, it was observed that where the lower Marshall section is abnormally thin, the overlying Napoleon beds are correspondingly thick and *vice versa*. This suggests that the top of the "Red-Rock" is not a stratigraphic horizon, but a result of local conditions during time of deposition. Additional evidence in support of this idea is given in subsequent paragraphs.

The Marshall formation can be divided into a lower and an upper section on lithologic grounds instead of on the color boundary that has been used heretofore. Invariably, the lower part of the Marshall section is much finer-grained than the upper part. In most well sections the change from fine to coarse sandstone is abrupt and easily observed. In a very few wells the change from fine to coarse was found to be gradational, but even thus an identifiable change occurs at the base of the relatively coarse sand in the upper part of the section. The thickness of this lower fine zone averages 60 feet. In most wells it varies only slightly from this figure, although in one well only 8 feet of fine sandstone was found at the base of the Marshall. Because of their fairly consistent thicknesses, these divisions of the Marshall are believed to more nearly represent stratigraphic units than the divisions used heretofore.

The fine sandstone of the lower Marshall consists mainly of quartz grains which are more angular than rounded. A small amount of calcium carbonate is

[20] *Op. cit.*, pp. 724–33.

[21] Lucille Hale, "Study of Sedimentation and Stratigraphy of Lower Mississippian in Western Michigan," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 4 (April, 1941), pp. 713–23.

present as cement. This sandstone breaks into fragments during drilling, whereas the overlying coarser sandstone is broken down by the drilling process into individual sand grains.

In nine of twenty-one sets of samples examined, the fine sandstone in the lower Marshall was white above the base for a distance of 6 to 20 feet. This is also true of two out of three wells in the Buckeye pool. In the remaining wells the lower zone was red down to the top of the Coldwater. In every well the red color continued upward at least as far as the top of the fine sandstone zone. The red color is due to hematite coating on the grains of quartz. Therefore, the color is due to environmental conditions during sedimentation, and not to the color of the sand grains themselves. Evidently the early Marshall sea contained abundant iron oxide which was precipitated as hematite.

Without exception, the upper Marshall consists of coarse angular sand grains. Many of the grains are frosted. The highest part of the upper zone is everywhere white, but the sand grains in the lower part may be stained red in the same manner as the underlying finer-grained sandstone. However, no difference other than this iron stain could be noticed between the white and red sandstones of the upper Marshall as defined in this study.

In one Buckeye and one Porter well, the top of the red coincides with the top of the fine sandstone. In the Porter well, however, the succeeding 50 feet of coarse sandstone is pale pink. In all of the other wells studied, the upper Marshall coarse sandstone is stained red for distances of 9 to 56 feet above the top of the fine-grained sandstone.

The average thickness of the upper Marshall is 140 feet, more than twice the thickness of the lower member. The top of the Marshall is very irregular. The overlying Michigan formation in a well in Sec. 16, T. 13 N., R. 1 W., extends 55 feet below the top of the Napoleon in Sec. 12, T. 13 N., R. 2 W. Similar occurrences have been noticed by both Newcombe[22] and Addison.[23] A favored explanation is that the upper Marshall or Napoleon sea was transgressing westward so that while sandstone was still being deposited at the westward side of the Porter area, Michigan sediments were being deposited in the eastern part of the district.

MICHIGAN FORMATION

The early Michigan sea was muddy, and the sediments deposited were mainly clastics. Then this body of water was cut off from the ocean and a period of dessication with deposition of evaporites followed. This cycle, of first clastics and then evaporites, was repeated during the Michigan stage.

In this report the first cycle of deposition, containing a lower zone (Zone 1)

[22] Robert B. Newcombe, "Oil and Gas Fields of Michigan," *Michigan Geol. Survey Pub. 38* (1932), pp. 81–82.

[23] *Op. cit.*, p. 1967.

of shale and limestone and an upper zone (Zone 2) of gypsum, shale, and limestone, is classified as lower Michigan; zones 1 and 2 of the second cycle are placed in the upper Michigan. The same zonation was recognized by Addison in the Buckeye samples, but he placed the boundary between the lower and upper Michigan sediments at the top rather than the base of the writer's Zone 1 of the second cycle.

The average thickness of the Michigan formation in the Porter area is 310 feet. The maximum thickness in the wells studied is 342 feet in a dry hole a mile beyond the northwest end of the field. The minimum thickness, 257 feet, is in the NE. ¼ of Sec. 16, T. 13 N., R. 1 W., where the next younger formation, the Bayport, is absent. The thinnest section of the Michigan underneath the Bayport is along the top of the Porter anticline in Secs. 2 and 12, T. 13 N., R. 2 W., where the thickness of the formation ranges from 280 to 300 feet. However, at this particular point, as the thinning is accompanied by a comparable thickening of the underlying Marshall formation, it is probably due to less deposition rather than to erosion.

The surface of the Michigan formation was modified by erosion in pre-Bayport time as shown by the irregularities in thickness of this formation where covered by the Bayport. But the pre-Saginaw erosion was of greater magnitude, for in two places on the Porter anticline it removed all of the Bayport and cut into the Michigan to varying depths. Between two wells in adjacent locations in Sec. 15, T. 13 N., R. 1 W., 48 feet of Bayport formation has been removed, and in a third well in Sec. 16, two locations west, not only all of the Bayport but also nearly 50 feet of the Michigan formation are missing.

The lowest zone (lowest Zone 1) of the Michigan is about 40 feet thick. It consists of gray shale and dark gray or brown limestone. It immediately overlies the light-colored sand at the top of the Marshall. Zone 2, immediately above, is between 70 and 80 feet thick and is composed of light-colored gypsum and gray shale and limestone.

Zone 1 of the upper Michigan, as here defined, separates the two gypsum members. It has an average thickness of 40 feet, and consists of either gray shale or brown limestone. This zone corresponds stratigraphically with the "brown dolomite" of other Michigan basin fields. Zone 2 of the upper Michigan is a mixture of white or salmon-colored gypsum, with gray to black shale and shaly limestone. Near the top of this member pyrite is common, and thin beds of brown dolomite may be present. Because the top is an erosion surface, there is no consistency in the character of the samples immediately below the overlying formation. The upper contact of the Michigan formation was drawn at the base of the Bayport sandstone, or where that has been removed, at the base of the Saginaw shale.

The thickness of Zone 2 of the upper Michigan ranges from 130 to 185 feet. At the Buckeye pool, where the same conditions of post-Michigan erosion existed, the maximum thickness found by Addision is 110 feet.

BAYPORT FORMATION

Following Michigan deposition was a period of emergence and erosion. As no evidence was obtained of any diastrophic movements in the Porter area during this time, the Michigan-Bayport contact here is considered an erosional unconformity only. During the next submergence sandstone and then limestone were laid down in the Bayport sea.

Pre-Saginaw erosion eliminated the Bayport in places. Its maximum thickness is 78 feet. The formation is absent in two wells on the north flank of the Porter anticline near the east end and in one well on top of the anticline near its northwest end. The Bayport thickens in all directions from these areas, and reaches a maximum beyond the borders of the pool.

The Bayport consists of basal sandstone 5 to 55 feet thick and brown or gray limestone with a maximum observed thickness of 57 feet. The sandstone is gray and friable. Its variable thickness is apparently due to inequalities in deposition, for considerable irregularity occurs even where it is overlain by limestone. The variation in the thickness of the limestone is due, in large part, to the episode of erosion that preceded Saginaw deposition.

PARMA AND SAGINAW FORMATIONS

Bayport sedimentation was followed by the deposition of extensive sand deposits of Parma age. The Parma deposits may represent the beginning of the late Paleozoic revolution when throughout the world lands were elevated and streams rejuvenated. Following Parma time came emergence and extensive erosion. At places the previously deposited Parma, the Bayport, and even the upper part of the Michigan rocks were removed. Then came the oscillating conditions during which the marine and continental shale, sandstone, and coal beds of Saginaw age were deposited.

The Parma sandstone is present immediately above the Bayport limestone in 7 of the 9 wells for which samples were available. In the remaining two wells the shales of the lower Saginaw rest directly on the Bayport. The Parma consists of friable white sandstone, with subangular grains. Where present, it has a maximum thickness in the Porter area of 110 feet, but most of the wells logged 30–40 feet.

In its lower part, the Saginaw invariably has from 35–155 feet of shale. The basal part of this unit may be gray shale, with black shale above, or the entire section may be black shale. Also present may be a few fragments of light brown shale (underclay?), coal, pyrite, and fine-grained highly indurated sandstone. No limestone was found. In two wells the entire section above the shale unit consists of fine to coarse white friable sandstone; in 7 out of 9 wells one or two shale breaks from 14 to 70 feet thick are present. Apparently sand was being deposited in some places while clay was accumulating elsewhere in the Porter area during late Saginaw time. The sandstone unit has a maximum thickness of 350 feet.

Above the upper Saginaw sandstone in the Pure Oil Company's Naramore No. 38 in Sec. 16, T. 13 N., R. 1 W., is 38 feet of pebbles derived from a wide variety of rocks, including limestone. These may belong to the Grand River group,[24] but are more likely a part of the glacial drift.

PLEISTOCENE DEPOSITS

With the possible exceptions noted in the preceding paragraph, no well samples of glacial drift are now available. The thickness of the drift in the Porter area is about 280 feet.

STRUCTURAL GEOLOGY

The Michigan basin was no doubt in existence throughout the span of history included in the sedimentation record. The Porter anticline is a fold on the southwest flank of this basin, but near its deepest part where most sediments are thickest. Although there is some indication (discussed in the preceding section) that some incipient folding occurred after Rogers City and Bedford deposition, the main post-Dundee folding did not take place until after Parma time. It may have been pre-Saginaw, as at Kawkawlin,[25] but the evidence for this at Porter is inconclusive.

The Porter anticline (Fig. 6), as mapped on the base of the Traverse, consists of a dome with its highest point in the NE. $\frac{1}{4}$ of Sec. 21, T. 13, N., R. 1 W., and a long spur extending from the west end of the dome to the northwest. The end of the spur is in the SE. $\frac{1}{4}$ of Sec. 34, T. 14 N., R. 2 W., 9 miles from the east edge of the dome. The anticline is widest east and west at the site of the dome where it measures nearly 3 miles; its narrowest width, $\frac{3}{4}$ mile, occurs where the sides of the spur pinch together in Secs. 1 and 11, T. 13 N., R. 2 E. The closure on the dome is about 50 feet and the structural relief more than 90 feet. The nodes on the spur drop from 20 feet below the top of the dome at the southeast end of the spur to 40 feet below near the northwest end. The elevation of the lowest level of production also drops 35 feet between the east and northwest ends of the Porter anticline.

ACCUMULATION OF OIL

The oil in the Porter field is confined to the upper part of the Porter anticline. Obviously, therefore, accumulation is structurally controlled. But in the anticline the porosity and permeability of the uppermost Dundee beds determines the reservoir capacity. That this capacity varies widely throughout the field is shown by the wide differences in yield of individual wells regardless of structural position. Except at the west end of the anticline the best wells (initial productions ranging 1,000 to more than 2,000 barrels) are not on the crest of the anticline,

[24] W. A. Kelley, "The Pennsylvanian System of Michigan," *Michigan Geol. Survey Pub. 40* (1936), pp. 206–14.

[25] Albert P. Latta, "Kawkawlin Structure as Reflected by Pennsylvanian-Mississippian Unconformity." Paper read before Michigan Academy of Science, Arts, and Letters, May 26, 1943.

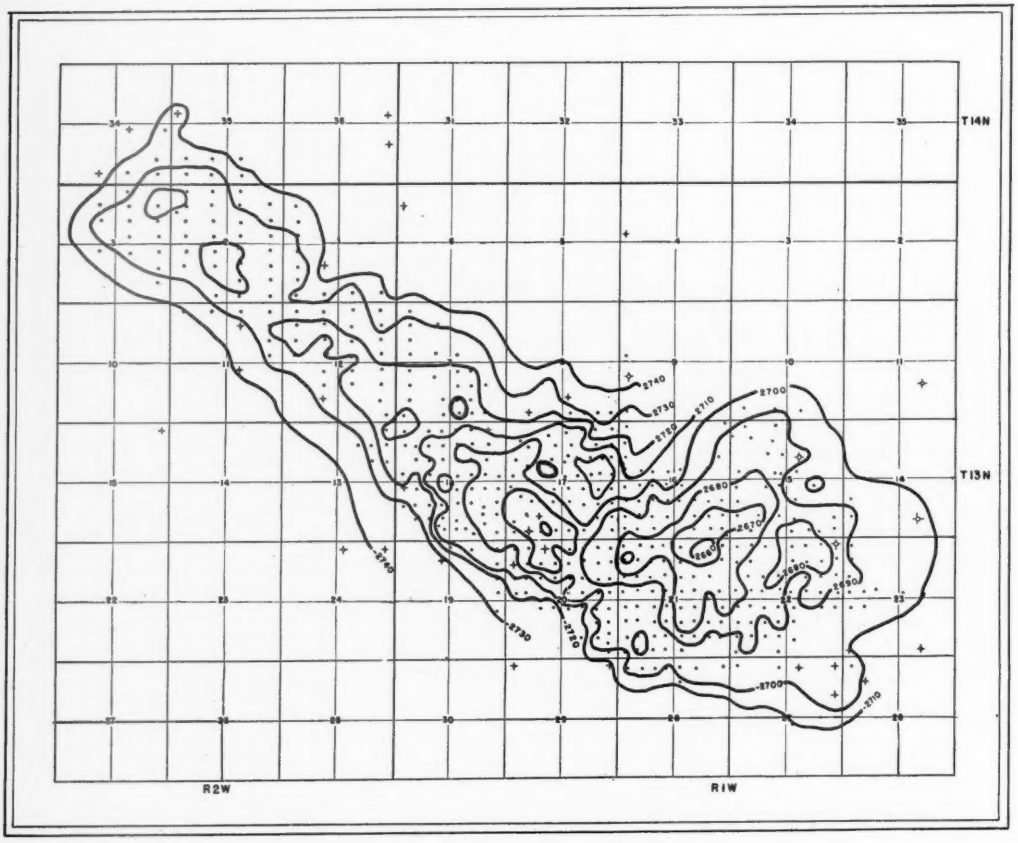

FIG. 6.—Structure map of Porter field, drawn on elevation of Rogers City-Traverse boundary. Contour interval is 10 feet. All elevations are below sea-level.

but are on the flanks. Within the same quarter sections, in some places, are other wells with initial productions of less than 50 barrels. On the south flank of the Porter anticline, in the SW. ¼ of Sec. 17 and the NW. ¼ of Sec. 20, T. 13 N., R. 1 W., is a group of dry holes completely surrounded by producing wells.

The examination of well samples from the Dundee verifies the existence of widely divergent porosity conditions. Two types of porosity occur in the Dundee: (1) initial porosity, and (2) secondary porosity. The latter is confined to the uppermost part of the Dundee (where present at all) and the zone of initial porosity lies lower in the section. Secondary porosity can be recognized easily in the cuttings, but as the initial porosity is probably intergranular in character it can not be seen in the finely crushed fragments. It is inferred by the presence of water. Max Littlefield, who has had wide experience in Michigan subsurface problems, makes the following comments on Dundee porosity: "Some of the initial porosity in fragmental, coquina-like limestone and coralline limestone has been enlarged by solution. In the dense lime the porosity is all secondary, the solution beginning in the calcite filling of contraction cracks, spore-case hollows, calcite filling of the rare fossils, and along stylolitic zones. There is evidence in some fields that post-Mississippian movement fractured the dense lime."[26]

The importance of the zone of secondary porosity lies in the fact that almost all of the Porter oil occurs in it. In no place where this zone is present is oil found in the lower zone of initial porosity. Where it is absent the zone of initial porosity may contain a showing of oil with the water, and in one well (S. ½, SW. ¼, SE.¼ of Sec. 10, T. 13 N., R. 1 W.), after acidizing, an initial production of 36 barrels was reported.

Littlefield[27] points out that other fields in the basin, for example, Kawkawlin, West Branch, and Bentley, which produce from Dundee initial porosity but slightly augmented by solution, have low initial yields and low total recoveries.

Cuttings from the zone of secondary porosity are shown in Figure 4. The Dundee has been leached into a honeycomb-like aggregate of cavities. The degree of leaching varies laterally. In some cuttings, as in the illustration, the cavities are relatively large and abundant. In others, they are smaller and less numerous. The thickness of the zone also varies from well to well. In some wells (as in the dry hole in the SW. ¼, SE. ¼, SW. ¼ of Sec. 17, T. 13 N., R. 1 W.) this zone is absent; in other wells it is as much as 30 feet thick. Invariably, however, the thickest zones have relatively poor porosity. Largest initial productions come from wells in which the secondary porosity is well developed throughout a zone ranging from 10 to 17 feet thick.

The zone of secondary porosity is just as erratic in percentage of porosity and thickness off the Porter anticline as on it. Of the six outside wells examined, no secondary porosity in the Dundee could be recognized in three, and the other

[26] Informal communication dated June 4, 1943.

[27] *Op. cit.*

three show from 4 to 20 feet. The quality of the porosity in the latter three is poorer than the average of the 23 wells on the anticline. From these data it may be assumed that secondary porosity is better developed on the fold than off.

The origin of the zone of secondary porosity presents an interesting problem. Obviously, this zone was produced after lithification of the limestone, and at a time when the top of the Dundee was close to the surface (in the zone of groundwater leaching). The writer originally suggested that the time of this leaching was during a post-Rogers City, pre-Traverse emergence when the relatively soluble upper Dundee beds were above the water table along the ancestral Porter anticline.[28] A re-study of the samples produced an alternative theory: that the leaching took place during a post-Dundee, pre-Rogers City emergence. The existence of an unconformity at the outcrop at this point has not yet been proved but evidence for it is accumulating.[29] The subsurface evidence of an erosional unconformity is more conclusive. Through the courtesy of the Gulf Oil Corporation the writer was able to examine a 5-foot core bridging the Rogers City-Dundee contact from a well drilled in Sec. 13, T. 24 N., R. 1 W. This core shows waterworn pebbles and corals of the Dundee in the basal Rogers City.

According to the second theory, the highest Dundee beds were relatively soluble and were leached into an exceptionally porous rock during the pre-Rogers City emergence. But as in the case of all limestones, the degree of solubility was not consistent. In some places the uppermost Dundee was honeycombed by solution, in others it was only slightly leached. This explains why some wells encountered very porous Dundee, containing a large quantity of oil, immediately beneath the Rogers City, while other wells found little or no porosity (hence, little or no oil) in this zone.

Regardless of how the zone of secondary porosity originated, it is responsible for the relatively high oil recovery per acre in the Porter field. The "trapping" of the oil is due to the anticlinal structure, but the quantity of oil stored in the reservoir is dependent on local porosity. The latter is largely dependent on conditions during a Devonian emergence.

PROSPECTS FOR DEEPER PRODUCTION

Only one well in the Porter field, the Carter No. 6 in the NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 18, T. 13 N., R. 1 W., penetrated pre-Dundee formations. This hole was drilled to the total depth of 4,733 feet, passing through the Detroit River formation and into the Sylvania sandstone. It was a dry hole in the deeper formations. However, as the well is on the southwest flank of the Porter anticline (as mapped on the base of the Traverse), it is structurally somewhat low. Furthermore, as the anticline is asymmetric with the steeper dip on the southwest side, the axis of the

[28] Paper read before Michigan Geological Society, March 10, 1943. Abstract published in Program, 28th annual meeting of the Association, Fort Worth, Texas, April 7–9, 1943.

[29] G. M. Ehlers, informal communication, May 30, 1943.

anticline probably shifts somewhat northeast with increasing depth. For these reasons it is doubtful if the Carter well was an adequate test of the oil possibilities of the older formations penetrated.

Since the development of the Porter field, oil in commercial quantities has been found in the Detroit River in at least 8 pools, and gas has been found in the Silurian at Kawkawlin. Ordovician formations are productive near the south rim of the basin.

The Porter anticline, a structural feature of considerable size, and a proved trap for oil in the Dundee, is worthy of thorough testing in the Detroit River and deeper formations, especially inasmuch as these strata are productive elsewhere in the Michigan basin.

PRODUCTION DATA

The Porter oil is reported to have a gravity in excess of 43° A.P.I.[30] Initial yield of the producing wells drilled on the Porter anticline ranged from marginal production to more than 2,000 barrels a day with the average probably between 100 and 200 barrels. The recovery per developed acre for the Porter (restricted) field is listed at 7,305 barrels; for the Yost-Jasper, 3,270 barrels.

The field was drilled almost exclusively with standard rigs. Because the reservoir rock is limestone, all wells were acidized, and some more than once.

PRODUCTION IN BARRELS[31]

Year	*Porter*	*Yost-Jasper*	*Total*
1931	944		944
1932	7,381	19,362	26,743
1933	3,354,175	219,485	3,573,660
1934	7,168,161	275,807	7,443,968
1935	8,317,098	874,762	9,191,860
1936	4,619,804	1,625,413	6,245,217
1937	2,706,708	1,158,341	3,865,049
1938	1,798,347	832,805	2,631,152
1939	1,330,992	594,655	1,925,647
1940	1,234,469	509,944	1,744,413
1941	1,136,076	405,543	1,541,619
1942	891,229	334,119	1,225,348
Total	32,565,384	6,850,236	39,415,620

In addition to oil, a part of the Porter area has been for years a source of brine which is piped to the Dow Chemical Company plant at Midland, where various other compounds, as well as salt, are recovered. The brine is pumped from a series of wells drilled along the west side of Porter Township. The producing brine formation is the Marshall sandstone. Since 1935 brine produced with the oil in the Porter field has also been pumped to the Dow plant as a brine-disposal project.

[30] Jed B. Maebius, *op. cit.*, p. 26.

[31] State of Michigan, Department of Conservation, Geological Survey Division (compiled from Tax Commission figures.)

Acknowledgments.—The well samples studied during the preparation of this report were loaned by the Pure Oil Company through Carl C. Addison, district geologist, Saginaw. In addition, Addison critically read the manuscript and supplied many pertinent data, including detailed information on the history of the Porter field. Jed Maebius, district geologist for the Gulf Oil Company, Saginaw, also perused the report and furnished additional information, especially concerning the one deep test in the Porter area. Ed. Baltrusaitis and Max Littlefield, likewise of the Gulf, have given information and advice regarding reservoir-rock conditions. The entire manuscript has been critically reviewed by the writer's colleagues, Professors Armand J. Eardley and G. M. Ehlers, and by Rex Grant of the Michigan Geological Survey, and Ira Cram of the Pure Oil Company.

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WEST RANCH OIL FIELD, JACKSON COUNTY, TEXAS[1]

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ABSTRACT

The West Ranch field is in the southwest corner of Jackson County, Texas. The discovery well of the main part of the field was the Magnolia Petroleum Company's West Ranch No. 3-A, which was completed in August, 1938. The field has nine producing zones, most of which are Frio in age. For a major field it is exceptionally free from faulting. Like most Gulf Coast fields the structure is probably due to the movement of a deep salt mass. No drilling difficulties are encountered in the field, and wells are completed in 12 to 15 days. The field covers approximately 10,400 acres, on which 390 producing wells have been drilled. Cumulative production to October, 1942, was 10,238,794 barrels of oil and 12,790,905,000 cubic feet of gas.

INTRODUCTION

The West Ranch field is herein described as of February 15, 1943.

Location.—The West Ranch oil field is located approximately 12 miles south of the town of Edna and one mile south of Vanderbilt, which is on the Missouri Pacific Railroad. It is in the southwest corner of Jackson County, Texas. About three-fourths of the West Ranch field, including the apex of the structure, lies within the boundaries of the 11,582-acre West Ranch. Southwest of the West Ranch field, are the Keeran, East Placedo, Placedo, Heyser, McFaddin, O'Connor, and Greta fields; whereas northeast are the Lolita, North LaWard, Maubro, Mauritz, and Withers fields. These fields lie almost in a straight line bearing N. 37° E. (Fig. 1).

Physiography.—In general, the topography of the West Ranch is typical of the Gulf Coastal Plain. The low, almost flat coastal plain dips gently south, and terminates in a bluff along the Lavaca River on the northeast side of the field, and north of Lavaca Bay and Venado Lakes on the southeast side of the field. Venado Creek bisects the field from northwest to southeast. On the northeast side of the field between the bluff and the Lavaca River are lowlands and the Menefee Lakes. Between the Lavaca River, Lavaca Bay, and the bluff on the south side of the field are four lakes along Venado Creek, which are also bordered by extensive lowlands. These flats are dry most of the year, and are used for cattle grazing. They are sometimes flooded, however, during severe gulf storms and after heavy rains in the interior when the Lavaca River overflows its banks.

History of discovery.—Surface indications consisting of gas showings in water wells, irregular topography, stream entrenchment, and significant surface sand distribution were reported by Homer A. Noble, geologist of the Magnolia Petroleum Company. Torsion-balance surveys and subsurface data from three early

[1] Manuscript received, June 21, 1943.

[2] Geologist, Magnolia Petroleum Company. The writer wishes to thank the Magnolia Petroleum Company for permission to publish this report. Thanks are also due to S. A. Thompson and Henry C. Cortes for helpful suggestions in the preparation of the manuscript, to the producing, petroleum engineering, and civil engineering departments, and especially to the following geologists of the Magnolia Petroleum Company, most of whom have worked in the field: P. H. Jennings, H. A. Noble, A. L. Morrow, J. C. Wold, J. B. Patton, and Bert C. Timm.

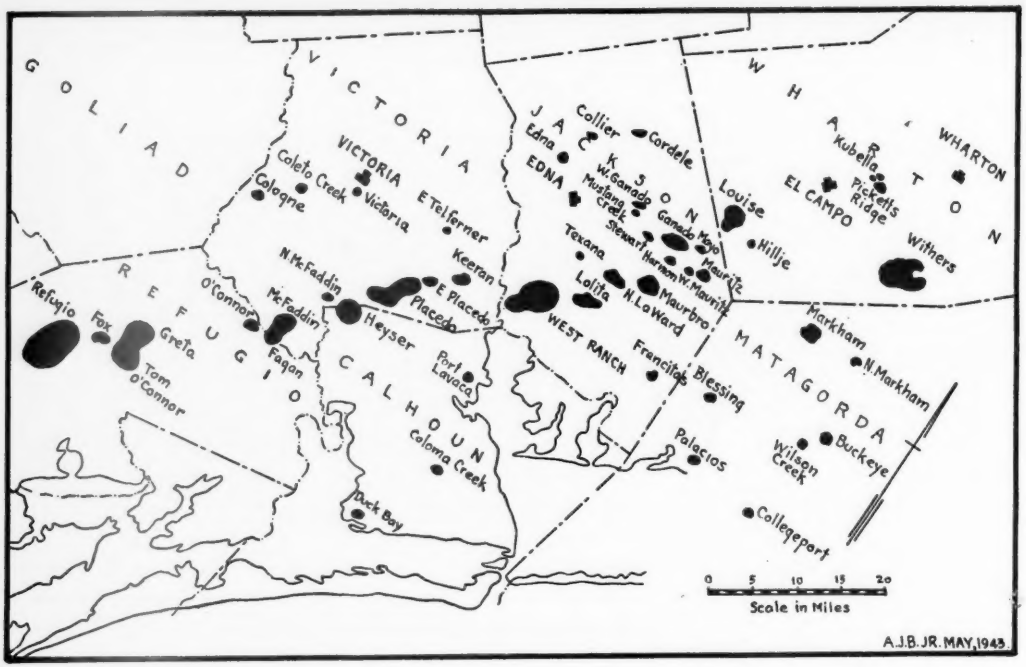

FIG. 1.—Map showing location of West Ranch field and relationship to other fields.

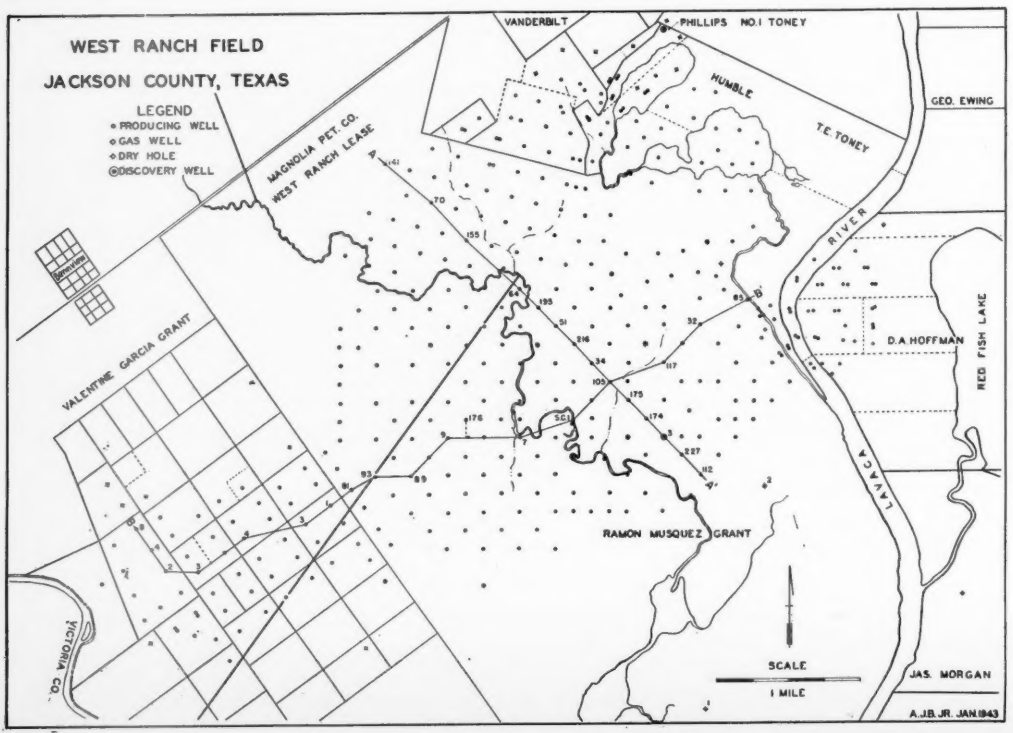

FIG. 2.—Map showing location of wells and electric-log cross sections.

wells also indicated the presence of a structural feature. These wells were the Continental Oil Company's Vincek No. 1, northwest of the field, and The Texas Company's I. N. Mitchell No. 1 and C. A. Mitchell No. 1, both of which were northeast of the field. In 1934 additional interest in the general area was created after the completion of a well in the vicinity of the town of Vanderbilt by the Encino Oil and Gas Company on the T. E. Toney farm in the Ramon Musquez Survey. However, subsequent drilling of dry holes around this well stopped any further development in this immediate area.

In the fall of 1937 the Magnolia Petroleum Company contracted for a reflection seismic investigation of its West Ranch lease. This work showed that the main anomaly was south of the Encino well, and led to the location of the West Ranch No. 1-A, which was dry but showed a subsurface feature. West Ranch No. 2-A was also a dry hole, but it had substantial showings of oil and gas and was considerably higher on the structure than No. 1-A. Following this, the Magnolia Petroleum Company continued its seismic work with its own crews. On the basis of this later work a third well, West Ranch No. 3-A, was drilled, and it resulted in the discovery of the West Ranch field (Fig. 2). This well was completed on August 26, 1938, in the West sand from 5,080–5,086 feet. The initial production was 133 barrels of oil per day on a 9/64-inch choke, with a tubing pressure of 325 pounds, a casing pressure of 810 pounds, and a gas-oil ratio of 100:1.

DATA AVAILABLE FOR STUDY

Paleontology and lithology.—Samples were saved from the first 30 or 40 wells drilled in the field by the Magnolia Petroleum Company, and detailed paleontological determinations were made from them. It was soon learned that the most reliable markers were an *Ostrea* bed at about 3,150 feet, the *Discorbis nomada* at about 4,450 feet, and *Marginulina texana* var. *vaginata* at about 4,940 feet.

While the wells were drilling, due to careful logging by the drillers, the change from the upper Catahoula sand to the *Discorbis* shale could be checked fairly accurately from the driller's log.

Coring.—During the early development of the field, all producing sands were cored solid with a wire-line core barrel, and detailed descriptions of each core were recorded. These cores were then sent to the Magnolia Petroleum Company's core laboratory for complete core analyses.

Electric logs.—Electric logs were run in every well drilled by the Magnolia Petroleum Company, and in most wells drilled by the other operators in the field. The electric logs are indispensable for correlation, as they are much more accurate and dependable than the paleontological markers. There are only two dependable paleontological markers in the West Ranch field, though many correlation points can be picked on every electric log. After a sufficient number of electric logs had been run in the wells to establish the location of the producing zones, the saving of cutting samples and a good part of the coring were discontinued for economic reasons.

The accumulated paleontological determinations, information from detailed core descriptions, results from core analyses, and a complete file of electric logs furnish a mass of data which are now available for a detailed study of the field.

SURFACE

The surface formations overlying the West Ranch field consist of black clay soil of Beaumont age and geologically recent flood-water deposits. Such recent deposits occupy a narrow strip along the west bank of the Lavaca River on the northeast and southeast sides of the field, and the bed of Venado Creek. The soil along Venado Creek is distinctly sandy, and it upports a dense growth of yaupon, post oak, live oak, et cetera. The black clay soil of the Beaumont Terrace supports a good growth of grass, mesquite, huisache, and hackberry. The flats which ie between the Beaumont Terrace and the Lavaca River on the northeast side of the field, and south of the Beaumont Terrace on the southeast side of the field, are covered mostly with sacahuisti grass. None of the land is under cultivation except a few small tracts on the west side of the field which are planted in cotton and corn. This is typical Gulf Coast ranch country, and the land is used almost exclusively for cattle grazing. The average elevation of the Beaumont Terrace is 29 feet, while elevations along Venado Creek vary from 17 feet on the northwest side of the field to 2 feet on the southeast side of the field. The average elevation of the flats along the Lavaca River and north of Lavaca Bay is 2 feet. The drainage on the conparatively flat Beaumont Terrace is generally poor except along Venado Creek. The rainfall is heavy during all seasons of the year—especially heavy during the winter months—which is typical of the Gulf Coast region.

SUBSURFACE

A generalized stratigraphic column as found in the West Ranch field and vicinity is shown in Table I.

TABLE I

GENERALIZED STRATIGRAPHIC COLUMN, WEST RANCH FIELD AND VICINITY

Age	*Formation*		*Lithologic Description*	*Approximate Thickness (Feet)*
PLEISTOCENE PLIOCENE AND MIOCENE	Undifferentiated	Beaumont	Black colloidal clay	4,000
		Lissie	Light-colored clays and fresh-water sands	
		Goliad	Light-colored clays and fresh-water sands	
		Lagarto	Yellow, blue, green and brown calcareous clays with a little sand	
		Oakville	Light-colored bentonitic clays and sands	
MIOCENE OLIGOCENE?	U. Catahoula		Ashy sands (often referred to as basal Miocene sand)	450
	Discorbis		Dark greenish gray, brittle, fossiliferous shale	300
	Heterostegina		Dark greenish gray, brittle, fossiliferous shale	100
	Marginulina		Dark greenish gray fossiliferous shale	150
	L. Catahoula		Shaly sands and clean sand	270
			Unconformity	
	Frio		Green and blue shales and sands	3,100
OLIGOCENE	Vicksburg		Gray, brownish gray and lignitic shales	?

PLEISTOCENE, PLIOCENE, AND MIOCENE

Beaumont, Lissie, Goliad, Lagarto, Oakville.—Since there are no reliable paleontological markers or lithological changes which can be readily recognized in sample cuttings from these formations, no attempt has been made to differentiate them. From the surface down these formations consist essentially of alternations of clays, fresh-water sands and gravels (to 1,500 feet), and vari-colored, mottled clays. Their approximate thickness over the West Ranch structure is 4,000 feet.

MIOCENE OLIGOCENE?

Upper Catahoula.—The Upper Catahoula formation in the West Ranch region consists of a thick body of sand broken here and there by thin shale streaks. This formation is often referred to by paleontologists as the basal Miocene sand. This is a regional blanket sand, and over the West Ranch field it has a thickness of approximately 450 feet. *Discorbis* is found in small numbers in the shale breaks near the base of the sand, but its occurrence here is rare.

Discorbis zone.—Immediately below the upper Catahoula sand is a fossiliferous shale marked by the sudden appearance of *Discorbis nomada*, which is generally accompanied by an associated fauna. This is the first reliable paleontological marker found in the West Ranch field, although *Discorbis* is found here and there in shale breaks near the base of the upper Catahoula sand. Over the West Ranch structure the *Discorbis* zone consists of greenish gray, fossiliferous, brittle shale with no included sand bodies. The approximate thickness of the *Discorbis* zone is 300 feet.

Heterostegina zone.—The *Heterostegina* zone is conformable under the *Discorbis* zone, and consists of dark greenish gray, brittle, fossiliferous shale. In other areas the top of this zone ordinarily contains *Heterostegina texana*, but in the West Ranch field *Heterostegina* and its associate fauna are either absent or very poorly developed. This zone can not be separated from the overlying *Discorbis* zone lithologically; and since *Heterostegina texana* is rare, *Bolivina perca* has been used to mark its top. Over the West Ranch pool the *Heterostegina* zone is very thin, consisting of about 100 feet of shale which contains no sand.

Marginulina zone.—*Marginulina texana* var. *vaginata* is the second reliable marker found in the West Ranch field, and also in this general area. However, *Marginulina idiomorpha* is found in some places approximately 100 feet above the first appearance of *Marginulina* var. *vaginata*, but its occurrence in this field is rare. The upper part of the *Marginulina* zone is composed of dark olive-green and greenish gray, brittle and fossiliferous shales, and the lower part consists of shaly sands and soft clean sand (Fig. 3). In many places a hard fossiliferous streak or shell bed has been observed down in the shaly sand section which contains abundant specimens of *Heterostegina texana*. The *Marginulina* zone has a thickness of approximately 420 feet in the West Ranch field.

Lower Catahoula.—The *Marginulina* sand zone is the lower Catahoula sand (Fig. 3). The thickness of this sand is variable, but in the West Ranch field it averages about 270 feet.

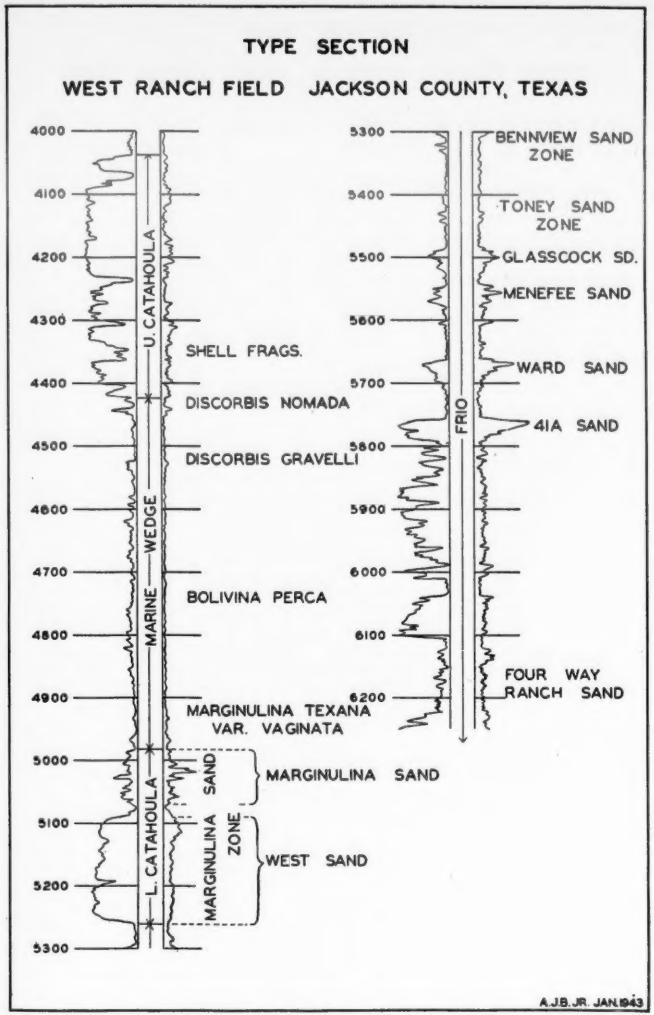

FIG. 3.—Type section in West Ranch field showing electric log, paleontological markers, and producing sands.

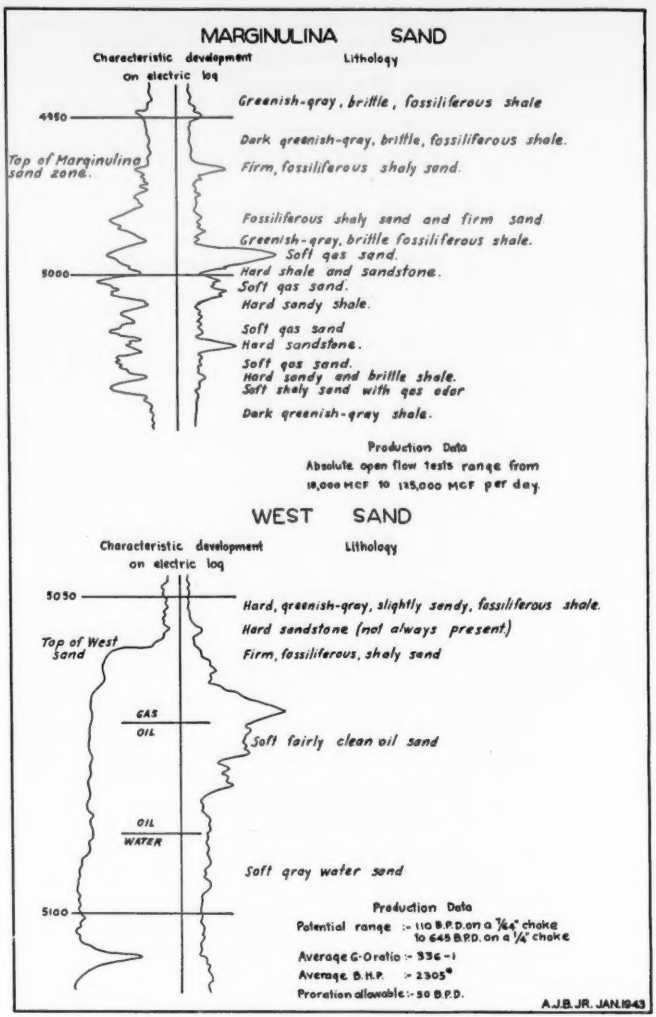

FIG. 4.—Diagram showing characteristic development on electric log and lithologic character of *Marginulina* and West sands.

Updip where the marine wedge of the *Discorbis*, *Heterostegina*, and *Marginulina* shale zones pinches out, the lower Catahoula merges with the upper Catahoula sand.

Frio.—Below the lower Catahoula sand, and separated from it by an unconformity, lies the Frio. A very noticeable lithologic change occurs here, as there is an abrupt change from the brownish gray and gray sand of the lower Catahoula to the blue and green brittle and hard shale of the upper Frio. Throughout most of its thickness of about 3,100 feet the Frio consists of blue and green, brittle and hard shale interbedded with numerous sand bodies of various thicknesses, which are ordinarily argillaceous and have a distinct blue color. Toward the bottom of the Frio the shales become more grayish in color; in places they are even lignitic; and finally they grade into the gray, dark gray, and lignitic shales of the Vicksburg.

Most of the oil zones of the West Ranch field occur in the Frio section.

OLIGOCENE

Vicksburg.—The Vicksburg underlies the Frio and consists of gray, dark gray, brownish gray and lignitic shales. It is sometimes differentiated from the Frio by a lithologic change, but more definitely by the appearance of *Textularia warreni*. *Textularia warreni* is poorly developed in the top of the Vicksburg in the West Ranch field. The thickness of the Vicksburg formation in this area is unknown inasmuch as each of the two deepest wells, West Ranch No. 1-A and West Ranch No. 105-A, went into the Vicksburg only a little more than 100 feet.

PRODUCING SANDS

There are nine known producing sand zones in the West Ranch field (February 15, 1943). Local names have been applied to these producing zones for convenience in making reports, maps, cross sections, *et cetera*. The names in descending order are: *Marginulina* sand (gas); West sand[3] (oil); Bennview sands (gas and oil); Toney sands (oil); Glasscock sand (oil); Menefee sand (gas); Ward sand (oil); 41-A sand (oil); and the Four Way Ranch sand (oil). The *Marginulina* and West sands are members of the lower Catahoula formation, and the remaining sands are members of the Frio formation.

Marginulina sand.—The *Marginulina* sand is made up of an alternating series of shaly sands and shales (Fig. 4). The top of the zone is shaly, tight, and not very porous. In the middle are some sands separated by streaks of tight sandy shale. These sand stringers are soft to firm and have fair permeability and porosity. The maximum thickness of any individual sand stringer in few places exceeds 20 feet, and the typical thickness is not more than 5 or 10 feet. The best development in the *Marginulina* sand occurs in wells on the northwest flank, and the poorest development is in wells on the southeast side of the field (Fig. 8). This is just the

[3] During the early development of the field this was erroneously called the "Greta" sand. It is apparent now that the top part of the *Marginulina* sand zone, as defined in the West Ranch field, is equivalent to the Greta sand of the Greta field, Refugio County, Texas.

reverse of the sand condition exhibited in the underlying West sand (Fig. 7). The *Marginulina* sand, or upper member of the *Marginulina* sand zone, has a total thickness of 90 feet, of which 40–50 per cent is shale. This sand blankets the field, covering 10,400 acres, and extends beyond the producing limits of all other producing sands. The gas-water contact of the *Marginulina* sand is at approximately −5,070 feet subsea.

This sand is correlated with the "Greta" sand, which is the producing sand of the Greta fie'd, Refugio County, Texas.[4]

Updip a short distance from the line of fields shown in Figure 1 the *Marginulina* and West sands, as used in this report, merge to fo m a solid sand body.

West sand.[5]—The lower part of the *Marginulina* sand zone is called the West sand because the first well completed in it was West Ranch No. 3-A. The West is a blanket sand whose oil zone is continuous over the top of the structure. The sand varies in thickness from 140 feet on the northwest flank to 225 feet on the southeast flank of the pool, but only the top part of the sand contains gas and oil (Figs. 4 and 8). It is below the water level in the west extension of the field. The sand is mostly very soft and mushy, but in some places the top 5–10 feet are shaly and fossiliferous, and, therefore, more firm. No core analysis could be made on the soft sand, but a few analyses of the shaly sand streak at the top of the sand show fair permeability and porosity. The gas-oil contact of the West sand is at −5,065 feet and the oil-water contact is at approximately −5,105 feet, subsea depths.

Completions in this sand were more satisfactory when the sand was perforated between −5,080 and −5,090 feet, that is, about midway between the gas-oil and the oil-water contacts. The reason for this is that the sand is very soft, and is not conducive to a perfect cement job. Wells completed high in the sand commonly developed gas trouble while low wells soon had water trouble.

Bennview sands.—The Bennview zone is made up of one and in places two discontinuous sand stringers which are best developed on the south and southeast flanks of the field. The main Bennview sand, or lower stringer, is continuous around the south, southeast, and east sides of the field, but the upper stringer appears and disappears from well to well. These stringers do not go over the top of the structure, but pinch out at about −5,380 feet subsea on the south flank, and at about −5,300 feet subsea on the southeast and east flanks. The sands range from fairly clean to blue argillaceous sand, and the thickness of the upper stringer is 5 or 6 feet, while that of the lower stringer ranges from 6 to 12 feet (Fig. 5). The lower stringer, or main Bennview sand, has its best development on the southeast flank of the field.

Toney sands.—The Toney sand zone consists of two discontinuous sand stringers which are very simi'ar in their lithologic characteristics to the Bennview sands

[4] R. A. Stamey, J. C. Montgomery, and H. D. Easton, Jr., "Greta Oil Field, Refugio County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4 (April, 1935), p. 544.

[5] R. A. Stamey *et al.*, *op. cit.*

(Fig. 5). Wells have been completed in the Toney sands on the southwest, south, southeast, east, and northeast sides of the field. The Toney stringers are 5–10 feet thick, and they become shaly over the top of the structure.

Glasscock sand.—The Glasscock is a blanket sand 40–45 feet thick in most parts of the field. However, on the southeast flank of the structure there is a sand

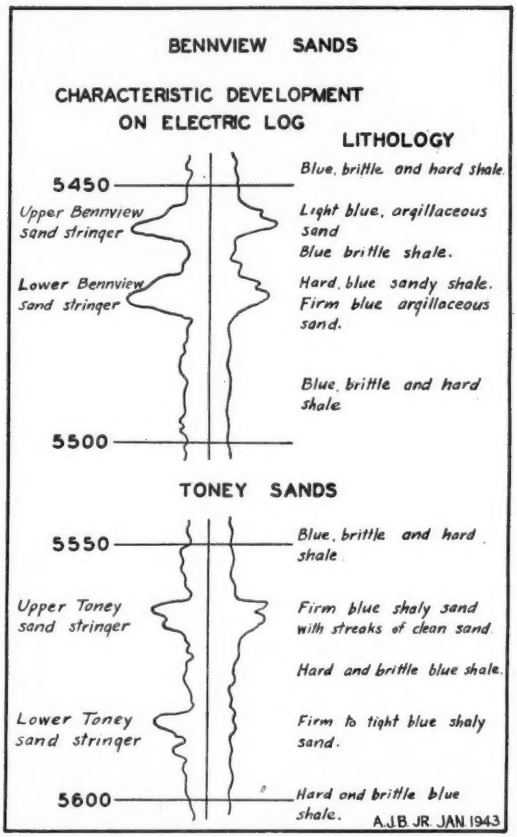

FIG. 5.—Diagram showing characteristic development on electric log and lithologic character of Bennview and Toney sands.

"build-up" on top of the Glasscock. This "build-up" is productive where it occurs within the oil interval of the Glasscock sand. The oil zone of the Glasscock does not extend across the top of the main structure, but forms a halo around the flanks with a large gas cap occupying the center of the field (Figs. 7, 8, 9). The

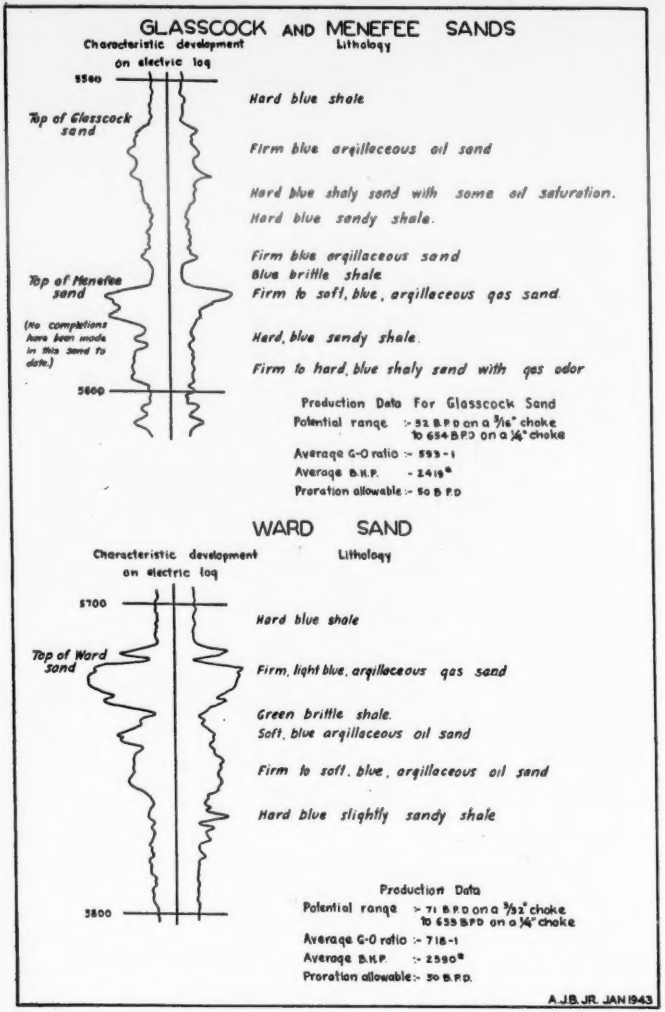
GLASSCOCK AND MENEFEE SANDS
Characteristic development on electric log
Lithology
5560
Top of Glasscock sand
Hard blue shale
Firm blue argillaceous oil sand
Hard blue shaly sand with some oil saturation.
Hard blue sandy shale.
Firm blue argillaceous sand
Blue brittle shale
Top of Menefee sand
Firm to soft, blue, argillaceous gas sand
(No completions have been made in this sand to date.)
Hard, blue sandy shale.
Firm to hard, blue shaly sand with gas odor
5600
Production Data For Glasscock Sand
Potential range :- 32 B.P.D on a 3/16" choke to 654 B.P.D on a 1/4" choke
Average G-O ratio :- 593-1
Average B.H.P. - 2419#
Proration allowable :- 50 B.P.D
WARD SAND
Characteristic development on electric log
Lithology
5700
Hard blue shale
Top of Ward Sand
Firm, light blue, argillaceous gas sand
Green brittle shale.
Soft, blue argillaceous oil sand
Firm to soft, blue, argillaceous oil sand
Hard blue slightly sandy shale
5800
Production Data
Potential range :- 71 B.P.D on a 5/32" choke to 635 B.P.D on a 1/4" choke
Average G-O ratio :- 718-1
Average B.H.P. :- 2590#
Proration allowable :- 50 B.P.D.
A.J.B.JR. JAN 1943

FIG. 6.—Diagram showing characteristic development on electric log and lithologic character of Glasscock, Menefee, and Ward sands.

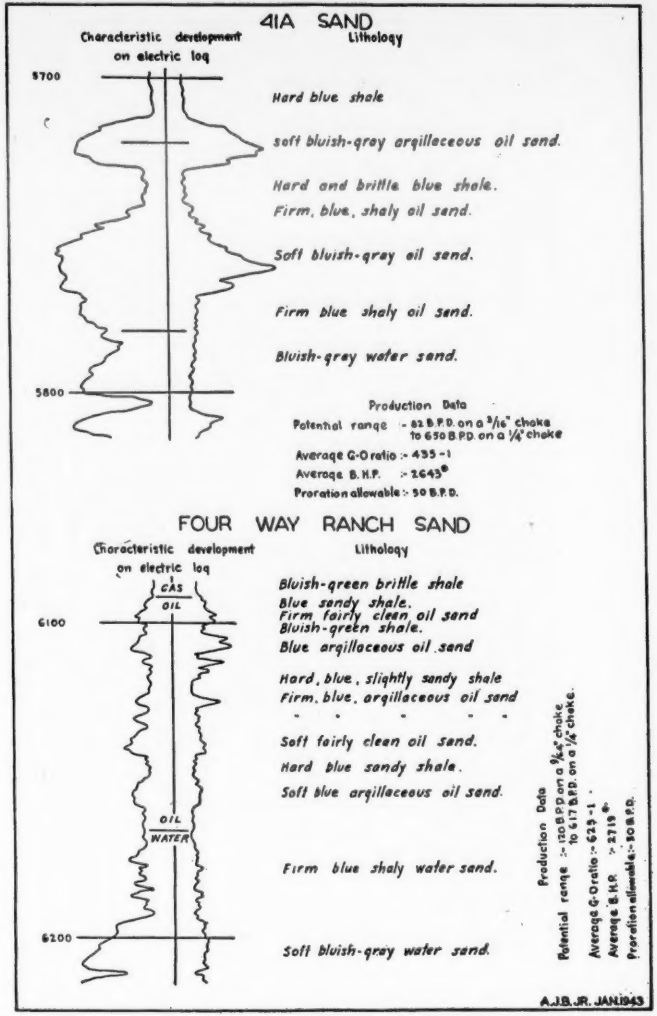

FIG. 7.—Diagram showing characteristic development on the electric log and lithologic character of 41-A and Four Way Ranch sands.

Glasscock is a firm, blue argillaceous sand with streaks of clean soft sand in the top 20 or 25 feet, and streaks of tightly cemented and shaly sand in the bottom 15 or 20 feet (Fig. 5). As a general rule it has been difficult to complete a low-ratio well in the lower part of the Glasscock sand, and this is especially true where this tight and shaly section is above −5,500 feet subsea. The softer and cleaner parts of the sand are well saturated and have good permeability and porosity. For the main part of the field the gas-oil contact is at about −5,475 feet, and the oil-water contact is at approximately −5,570 feet, subsea depths. An interesting fact should be brought out at this point: while production from the Glasscock sand extends across the saddle from the main part of the field to the west extension, the gas-oil and oil-water contacts are not the same for the two areas. The gas-oil contact is 70 feet lower in the west extension, or −5,545 feet subsea (Fig. 8), which is also the elevation of the lowest part of the saddle, while the oil-water contact is about 10 feet higher or −5,560 feet subsea. This leaves an oil interval of only 15 feet for the Glasscock sand west of the saddle.

Menefee sand.—The Menefee sand zone consists of about 35 feet of soft to firm, blue argillaceous, fine- to medium-grained sand, grading downward into firm and hard blue shaly sand. It is separated from the Glasscock by 5–8 feet of brittle and hard blue shale (Fig. 6). This sand made dry gas on several drill-stem tests, and to date no commercial oil has been found in it. It is a blanket sand whose producing area is 4,700 acres, which indicates a considerable gas reserve. The water level for this sand is −5,570 feet.

Ward sand.—The Ward sand blankets the field and has a large gas-cap area. The oil zone is confined to a narrow band around the flanks of the field except in the west extension area, which is separated from the main field by a low saddle. Here the oil zone extends over the top of the structure, and is also productive across the saddle (Fig. 8). The Ward sand zone is made up of interbedded firm blue argillaceous sand, soft blue argillaceous sand, some fairly clean sand, and a few thin stringers of blue brittle shale. The whole zone has a thickness of about 45 feet. The gas-oil contact of this sand is −5,705 feet and the oil-water contact is −5,730 feet, subsea. Permeability, effective porosity, and oil saturation in the Ward sand are good in the softer and cleaner parts. The softer and cleaner streaks are ordinarily near the top of the sand, and where these occur above the gas-oil contact (−5,705 feet), it is difficult to complete a low-ratio well. This is especially true in the west extension area.

There is a sand stringer or "build-up" a few feet above the main Ward sand which varies in thickness from 4 to 8 feet. It is very irregular in its occurrence, and is present on the northwest, east, and southeast flanks of the structure. On the northwest edge of the field this sand "build-up," where present, is exceptionally thick, and forms almost a solid sand body with the main Ward sand. However, its limits are so abrupt that it can not be predicted from one well to the next. This stringer is productive when it falls within the oil zone of the Ward sand.

41-A sand.—This sand has an oil interval of 60 feet, and is the best developed

in the field, although it shows considerable lateral variation. Some wells show 60 feet of practically solid sand, but in others the sand is divided by shale lenses into two, three, and four separated sand bodies. This sand zone covers 3,000 acres in the main part of the field, and has a relatively small and thin gas cap. The 41-A sand is below the water level in the west extension of the field. The sand is firm to soft, bluish gray, argillaceous, medium- to fine-grained, and is in places interbedded with shale lenses varying in thickness from a few feet to 10 or 12 feet (Fig. 7). This zone has an oil-gas contact at −5,690 feet and an oil-water contact at −5,750 feet, subsea. The permeability, effective porosity, and oil saturation of the 41-A sand are generally good.

Four Way Ranch sand.—This sand zone covers 2,500 acres, which is the smallest area of any of the main producing sands. It is below the water level in the west extension area. The oil interval in this zone is 75 feet thick, but the sands show much lateral variation. The zone consists of an alternating series of blue shaly sands and shales which are very irregular in development (Fig. 7). The shaly sand streaks are commonly firm, but some of the cleaner streaks are fairly soft. Analyses show these sands to have fair permeability, effective porosity, and oil saturation. The gas-oil and oil-water contacts of this zone are −6,070 feet and −6,145 feet, respectively.

STRUCTURE

Regionally the West Ranch field is one of several fields located along a probable zone of crustal weakness. Deeply buried salt masses pushing up along this zone are reflected by the structures of the various fields shown in Figure 1.

Locally, the West Ranch structure consists of two rather irregular oval areas—one large and one small—connected by a saddle (Fig. 10). It measures approximately 32,000 feet along its long axis, N. 62° E., and 20,000 feet along its short axis, S. 28° E. The areal extent of the field is roughly 10,400 acres.

The field derives its production from nine producing zones which are members of the lower Catahoula and Frio formations. The gas-producing zones of the *Marginulina* and Menefee sands, and the oil-producing zones of the West, 41-A, and Four Way Ranch sands extend across the top of the structure, but those of the Bennview, Toney, Glasscock, and Ward sands do not. The Bennview and Toney sands pinch out against the flanks of the dome, but the Glasscock and Ward sands have large gas caps over the center of the field (Figs. 8 and 9), and produce oil only in a halo-like area on the periphery of the dome.

Attention has already been called to the fact that the gas-oil contact of the Glasscock sand in the main part of the field is different from that in the west extension area. This may be seen in electric log cross section *BB′* (Fig. 9). For some inexplicable reason the gas bubble which was trapped in the lower structure of the west extension area was not flushed out as the oil accumulated in the main and higher part of the structure.

Figures 10, 11, 12, and 13 are structure contour maps of the field drawn on top of the West, Glasscock, Ward, and 41-A sands. Roughly, the beds dip away from the top of the structure at the rate of 150 feet per mile on the north flank, 80 feet

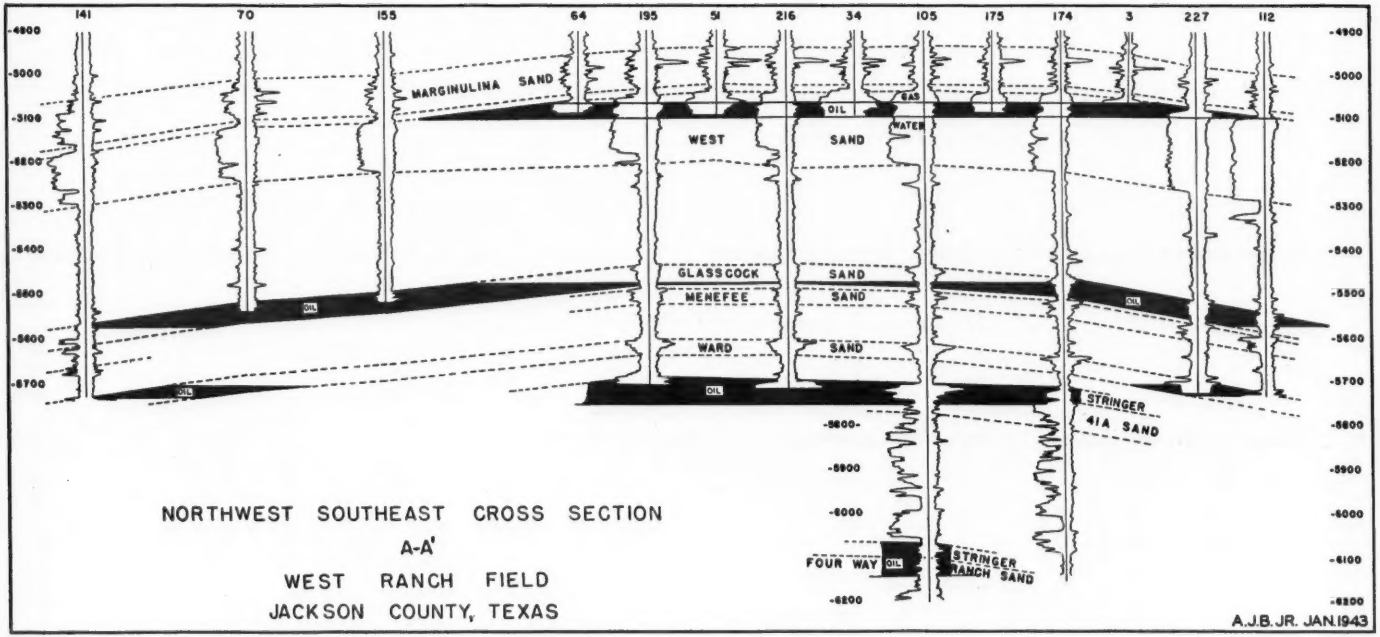

FIG. 8.—Cross section *AA'*. See Figure 2. All wells used on cross section *AA'* are Magnolia Petroleum Company wells.

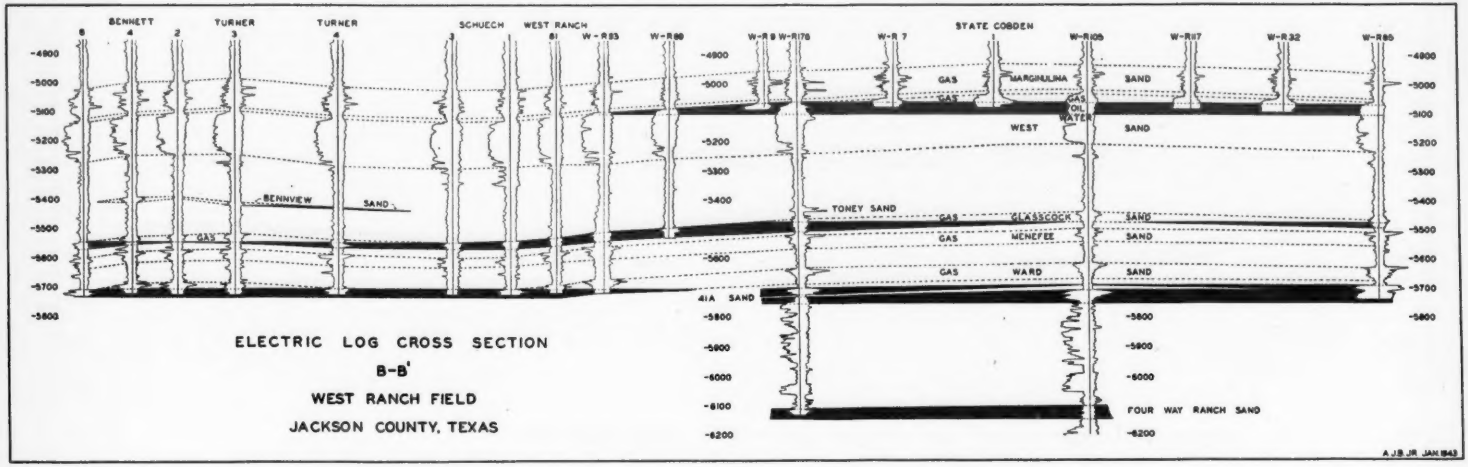

FIG. 9.—Cross section *BB'*. See Figure 2. All wells used on cross section *BB'* are Magnolia Petroleum Company wells.

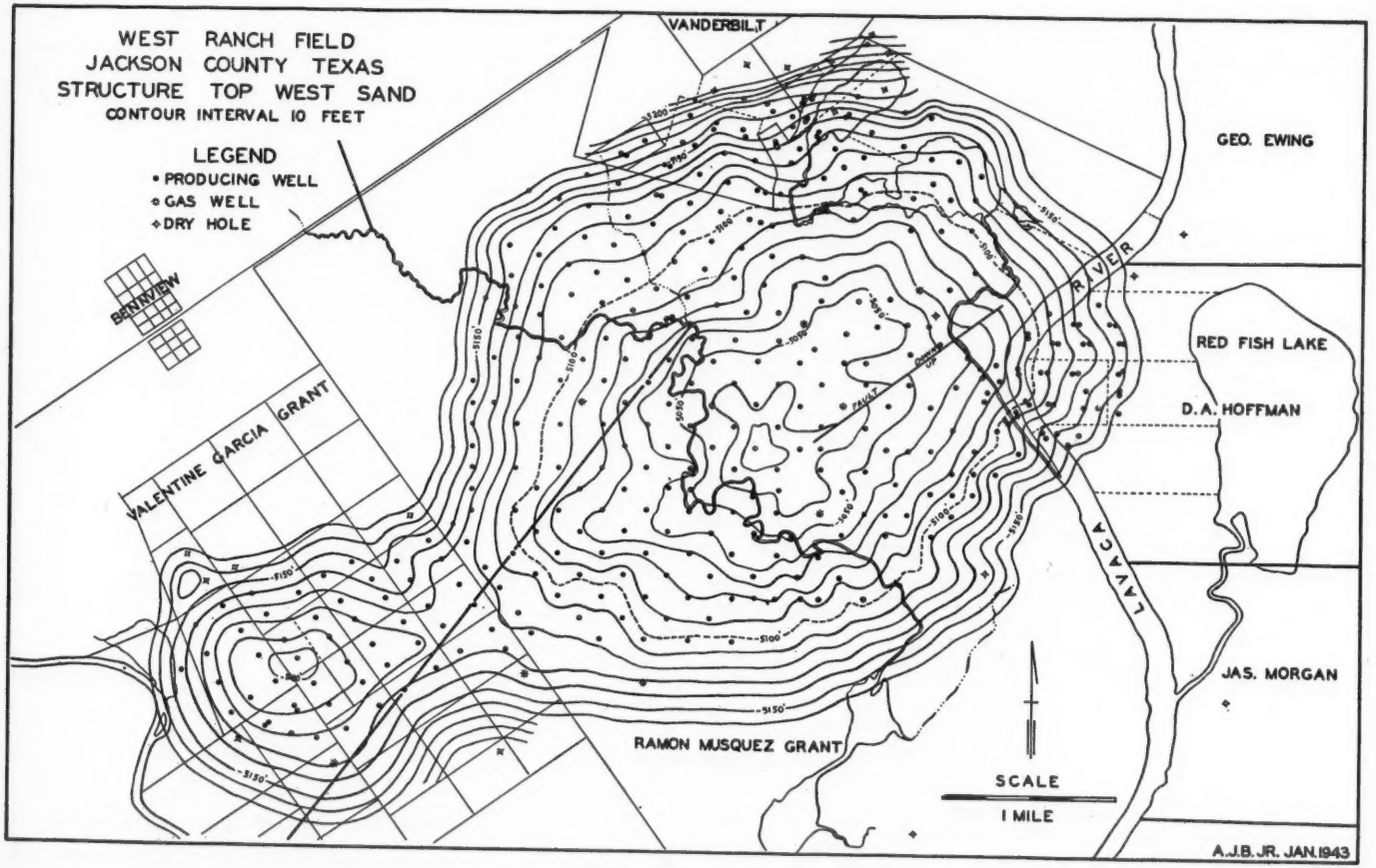

FIG. 10.—Structure-contour map drawn on top of West sand.

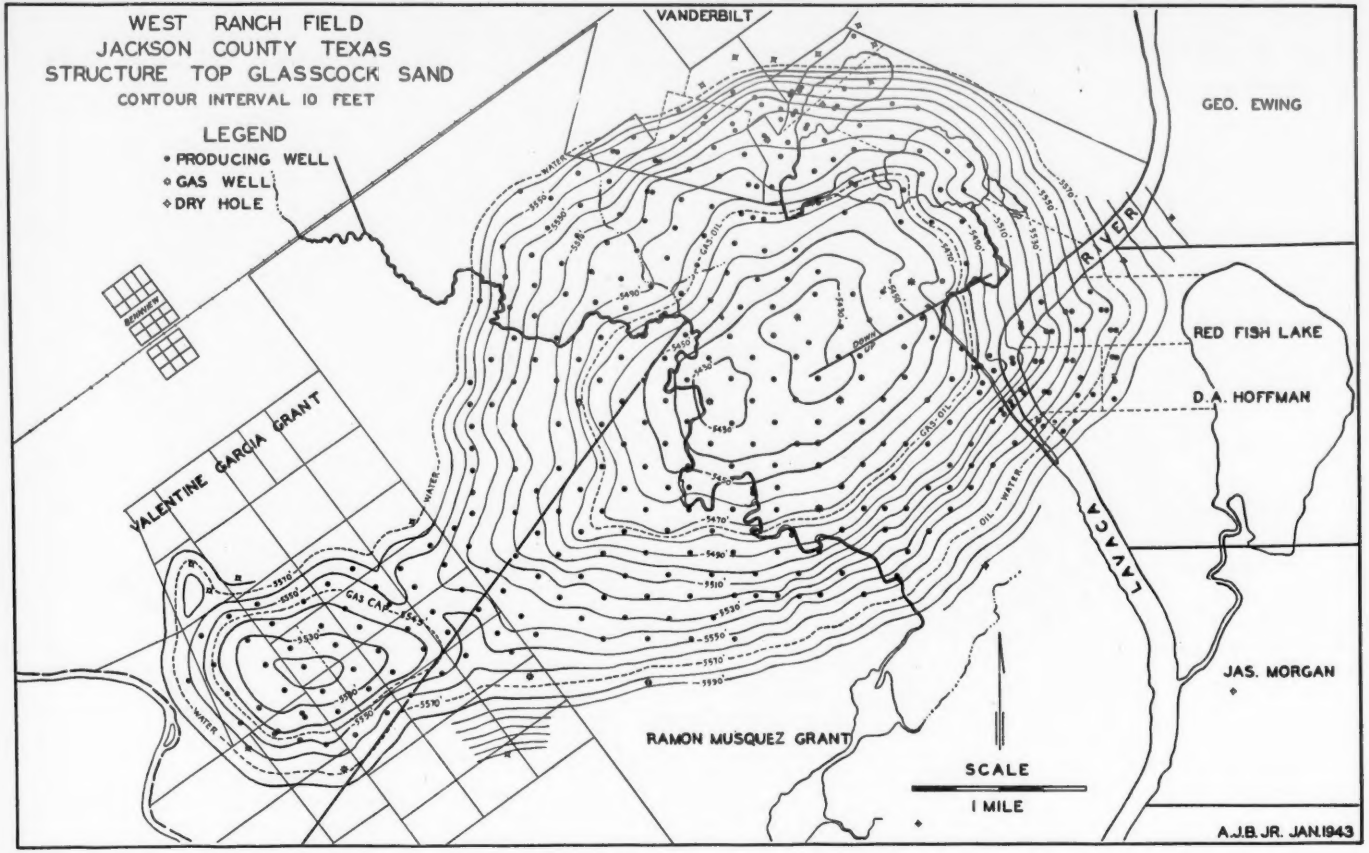

FIG. 11.—Structure-contour map drawn on top of Glasscock sand.

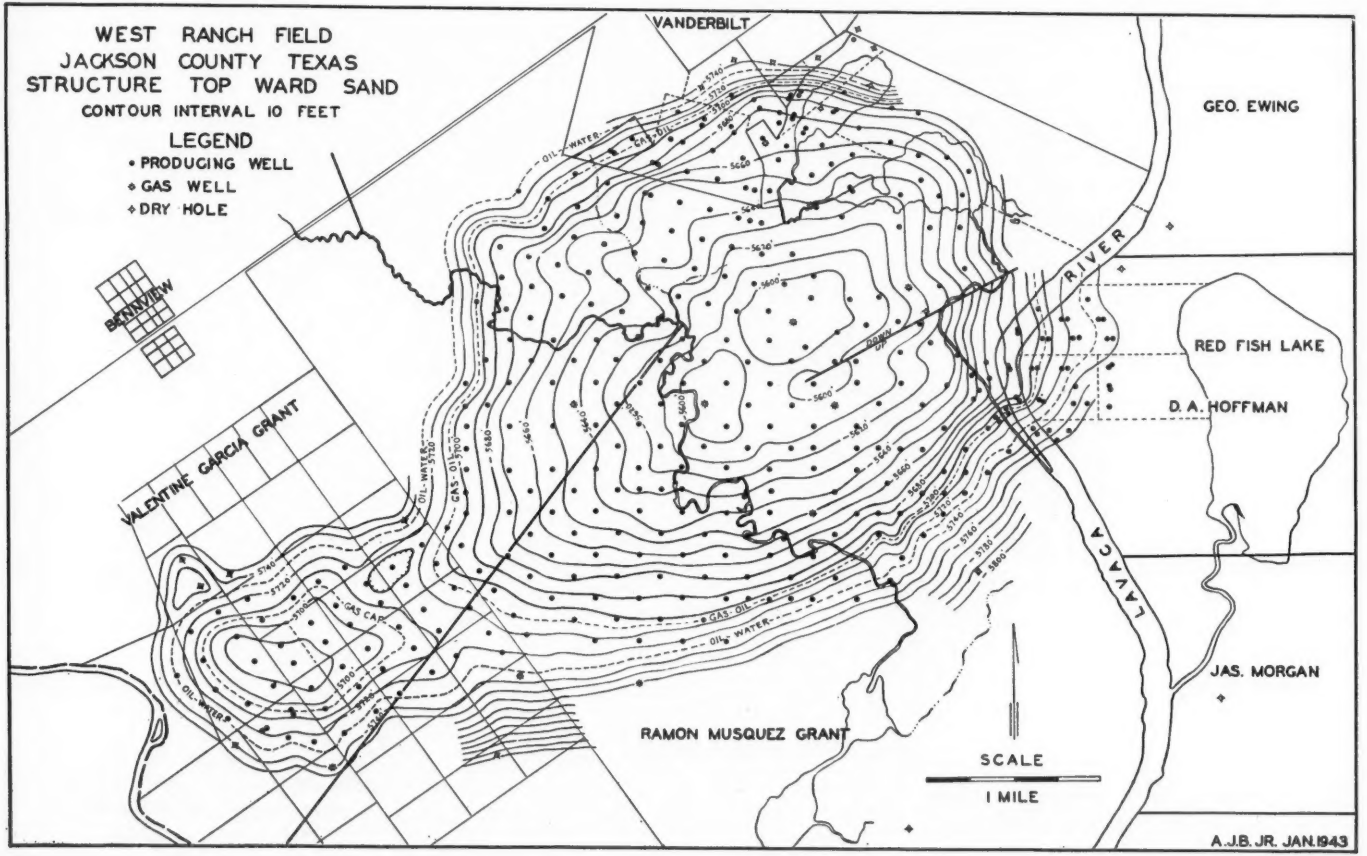

FIG. 12.—Structure-contour map drawn on top of Ward sand.

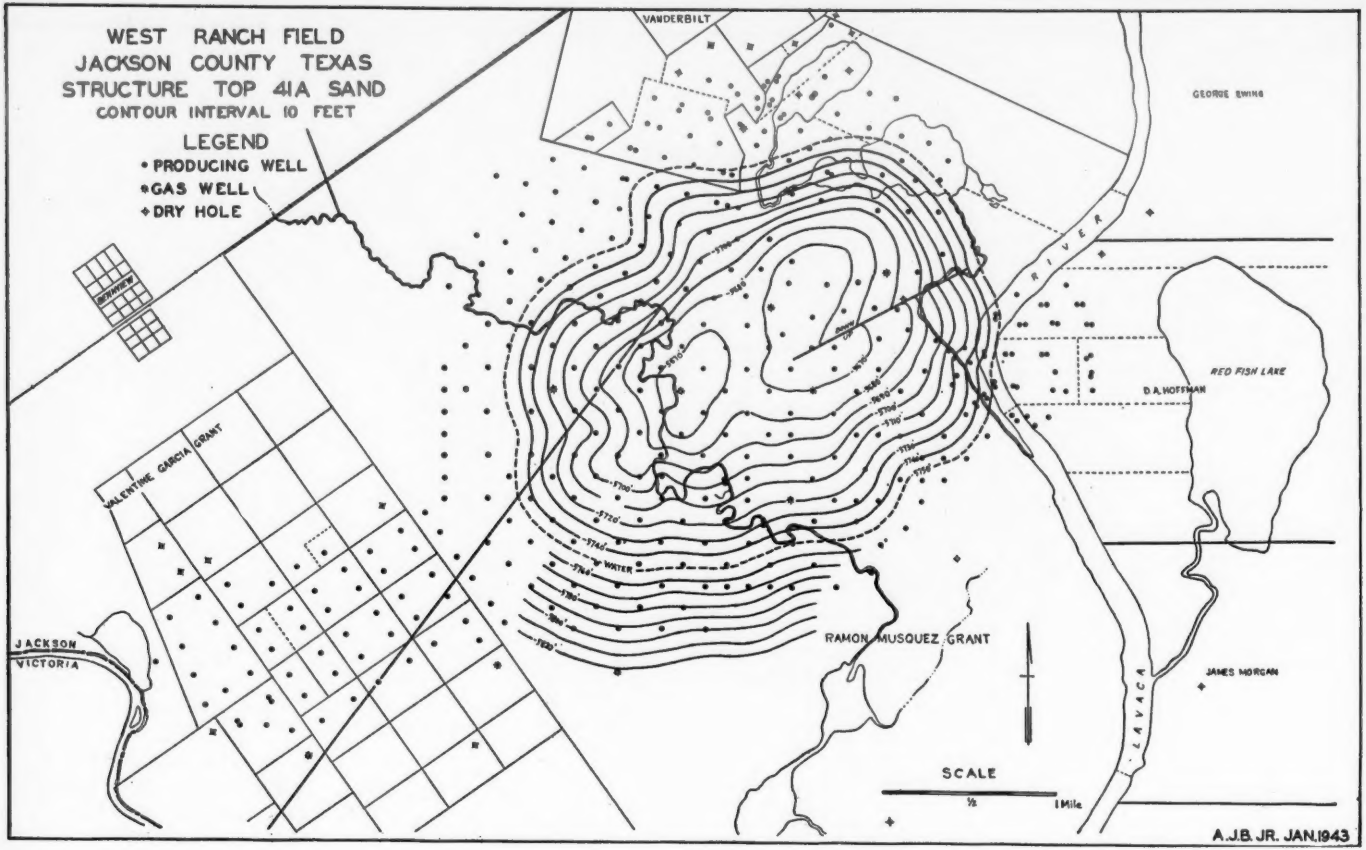

FIG. 13.—Structure-contour map drawn on top of 41-A sand.

per mile on the east and west flanks, and 100 feet per mile on the south flank. It can also be seen from the contour maps that the crest of the structure has migrated slightly updip with depth.

One of the more interesting features of this structure is the lack of major faulting in a field of this size.

PETROLEUM DEVELOPMENT

The first well drilled on the Magnolia Petroleum Company's West Ranch prospect was West Ranch No. 1-A. Its location was 6,952 feet west and 505 feet south of the northwest corner of the J. H. Bell Survey. The well was spudded on November 24, 1937. Two showings were logged: one from 5,290 to 5,302 feet, and the other from 6,490 to 6,494 feet. A drill-stem test from 5,290 to 5,303 feet recovered 135 feet of mud with no pressure; and a drill-stem test from 6,486 to 6,494 feet recovered 1,800 feet of salt water with no pressure. The well was abandoned in the top of the Vicksburg formation on March 18, 1938, after reaching the total depth of 8,527 feet.

TABLE II

NUMBER OF WELLS COMPLETED IN EACH SAND AND CUMULATIVE PRODUCTION TO OCTOBER 31, 1942, WEST RANCH FIELD

Companies	*Producing Sands*								
	Marginulina Gas Sand	*West Sand*	*Bennview Sand*	*Toney Sand*	*Glasscock Sand*	*Ward Sand*	*41-A Sand*	*Four Way Ranch Sand*	*Total*
Amer. Liberty			1		5	3			9
S. Boyle			4	3	1				8
L. Crouch			3	1	2	2			8
Darby Petrol. Co.						5			5
Forest Dev. Co.					4	2			6
Glasscock					9	5	1		15
Humble	1				27	4	3		35
Magnolia	7	70	1 Gas	2	78	60	32	6	256
Mid-States						1			1
Phillips			1	1	2	3			7
Renwar						4			4
Seaport					1	1			2
Seible					1				1
Shell						9			9
Stanolind	1		2		6	3			12
Superior					3	2			5
W.R.R. Oil Co.					4	3			7
Total	9	70	12	7	143	107	36	6	390
Cumulative Production to Oct. 31, 1942	12,790,905 M.C.F.	2,226,495	187,853	348,823	4,004,749	2,778,233	584,362	108,279	10,238,794

West Ranch No. 2-A was located 8,200 feet N. 15° E. of No. 1-A, and was spudded on April 19, 1938. It was drilled to 7,218 feet, and several oil shows were logged. Seven-inch casing was set at 5,680 feet, and several attempts were made to complete it as an oil well; but it was finally abandoned as a dry hole.

Wells Nos. 3-A to 12-A were drilled on an east-west line, and were spaced 1,320 feet apart, or one well to 40 acres. In general, this spacing was used on the West Ranch except along property lines where offset wells had to be drilled. The spacing of wells on leases off the West Ranch is irregular due to the varying sizes and shapes of these leases; but where possible, wells are usually located 467 feet from property lines.

Under ordinary drilling conditions it is possible to complete a well in 12–15 days. Three hundred and ninety producing wells and twelve dry holes have been completed in the West Ranch field between August, 1938, and February, 1943 (Table II).

Proration has been maintained since the discovery of the field; consequently, gas has been conserved; and on February 1, 1943, all producing wells are still producing by natural flow.

DRILLING METHODS

All wells in the West Ranch field were drilled with rotary-drilling tools. The usual equipment included either a 122-foot or a 136-foot steel drilling derrick, two 126-horsepower boilers, two boiler feed pumps, two 5 Kw. generators, two turbines, one tank-exhaust water heater, two 14½-inch×7½-inch×18-inch slush pumps, two 13⅜-inch blow-out preventers, one 7½ Ideal unitized draw works, one 12-inch×12-inch twin-cylinder steam drilling engine, a 27½-inch rotary, one shale shaker, 4½-inch drill pipe with two 6-inch×30-foot drill collars on the bottom, and a wire-line coring unit.

In the earlier stages of development by the Magnolia Petroleum Company the common practice was to set about 1,300 feet of 13⅝- or 10¾-inch surface pipe, then 7-inch casing to the producing sand. After approximately the first sixty wells were completed, the casing program was changed to 9⅝-inch for the surface pipe and 5½-inch for the production string. Exceptions to this program were wells drilled along Venado Creek and on the flat on the east side of the field, where about 73 feet of 13⅜-inch conductor pipe was set; and in wells completed for gas, where 7-inch casing was used for the production string.

The completion method used by the Magnolia Petroleum Company in the first few wells was to set casing and screen just below the top of the oil sand. After the gas and water contacts of the various producing sands had been worked out, the production string was set well down in the oil sand and perforated. This gave a better opportunity to re-work wells which later on might develop high gas or water trouble. After perforation of the casing, 2-inch tubing was run to within a few feet of bottom, and the drilling mud was replaced with water. Usually the wells come in with their own pressure as soon as the mud is replaced with water. In some sections of the field, however, wells have to be swabbed in, especially those completed in the Glasscock sand.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 2 (FEBRUARY, 1944), PP. 217-230, 9 FIGS.

GEOLOGIC FACTORS IN UNITIZED PRESSURE MAINTENANCE, JONES SAND RESERVOIR, SCHULER FIELD, ARKANSAS[1]

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ABSTRACT

The Jones sand reservoir in the Schuler field, came under unitized operation on February 15, 1941. Gas injection commenced on July 1, 1941. Under unitized injection of 90 per cent of the produced gas volume, it is estimated that the ultimate recovery will be 20,000,000 barrels of oil more than would have been recovered under a continuation of ordinary primary methods.

The effectiveness of the pressure maintenance operations is controlled by the reservoir characteristics. Some of the most important of these characteristics have been accurately recorded from laboratory analyses of cores, which were taken in nearly all wells, and the study of these data has provided a sound basis for these operations.

"Core graphs" include core-analysis data, electric-log diagrams, and drilling time. These graphs bring out whatever correlations exist between core data and electric logs. Gas-oil contact is clearly indicated and permeability variation is one of the most prominent features.

Cross sections made up of core-permeability profiles bring out the absence of continuity of shaly or silty zones of low permeability or of zones of high permeability; this absence of continuity represents very favorable conditions for the gas-cap type of pressure maintenance.

INTRODUCTION

Weeks and Alexander discussed the geology of the Schuler field and development to July, 1940.[3]

The Jones sand was discovered September 17, 1937, and to the end of 1942 had produced 25,550,000 barrels of oil. Figure 1 is a structure map drawn on top of the Jones sand and shows the 140 wells of the Schuler unit. The highest Jones sand top was cored at 7,251 feet subsea in the Phillips Petroleum Company's Marks No. 3, occupying a position between Schuler unit Nos. 75 and 85; the lowest top cored in a productive well was 7,362 feet subsea in the Phillips' Edwards No. 1, Schuler unit No. 69 on the northeast edge; this represents a productive structural closure of more than 111 feet.

The structural character of the Jones sand reservoir is represented in Figure 2, longitudinal section AA' (Fig. 1). Average original gas-oil and oil-water contacts are shown. The same illustration also shows this section drawn to the same scale, vertical and horizontal, in order to present a picture of the reservoir in its true proportions.

UNITIZATION

Early in the history of the development some of the operators recognized the importance of unitizing the Jones sand, but efforts were unsuccessful until February 4, 1941. At that time all operators but one presented to the Arkansas Oil and Gas Commission a unit-operation agreement and a royalty-pooling agreement,

[1] Presented before the Association at Forth Worth, April, 1943. Manuscript received, July 14, 1943.

[2] Phillips Petroleum Company.

[3] Warren B. Weeks and Clyde W. Alexander, "Schuler Field, Union County, Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 9 (September, 1942).

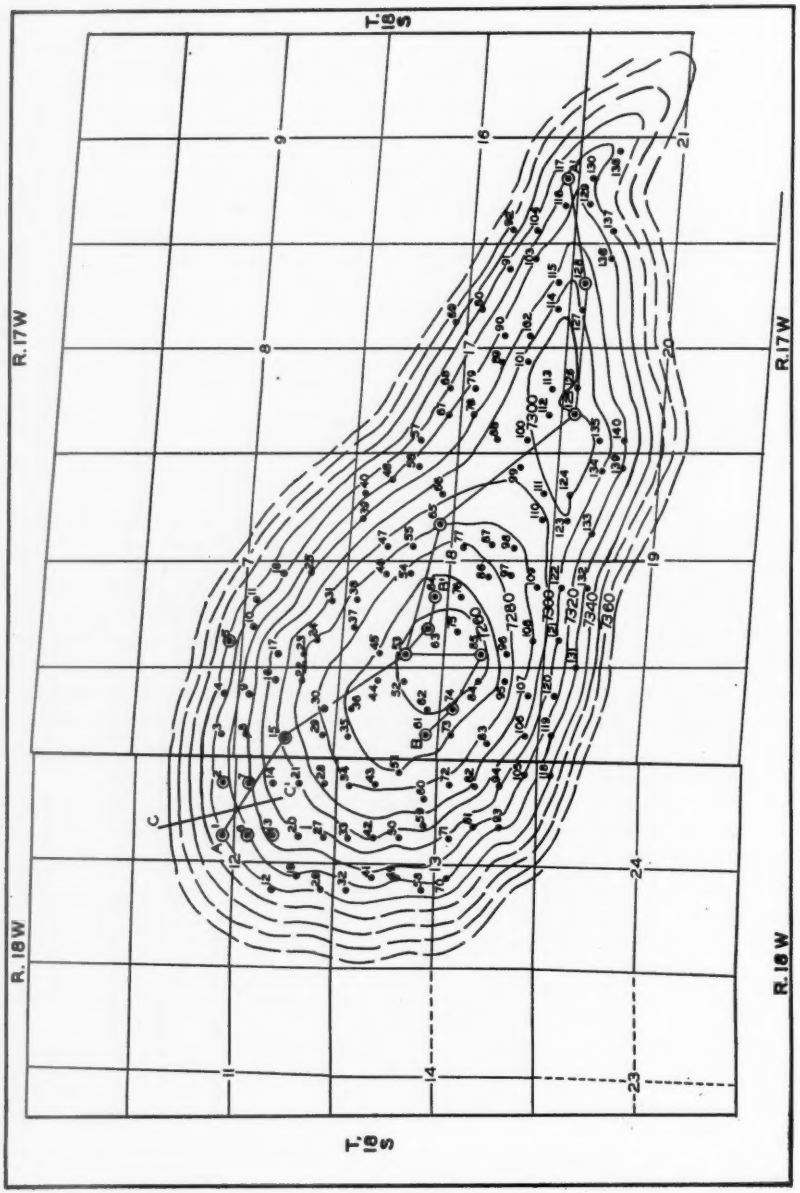

FIG. 1.—Structure-contour map, Jones sand, showing cross sections.

executed by more than 185 persons who owned more than 75 per cent of all the royalty.

It was ordered that after 7:00 A.M., February 15, 1941, the operator of the unitized area might produce all of the oil permitted to be produced from the unitized area, from any well or wells then situated in the unitized area; and it was ordered that such oil should be produced in a manner which would tend to utilize the minimum quantity of free gas or gas in solution.

The unitization covered the full royalty and working interest in all but 6 wells of the 146 Jones sand producers. The Lion Oil Refining Company at El Dorado, Arkansas, was elected unit operator subject to a Unit Operators' Committee representing the twelve owners.

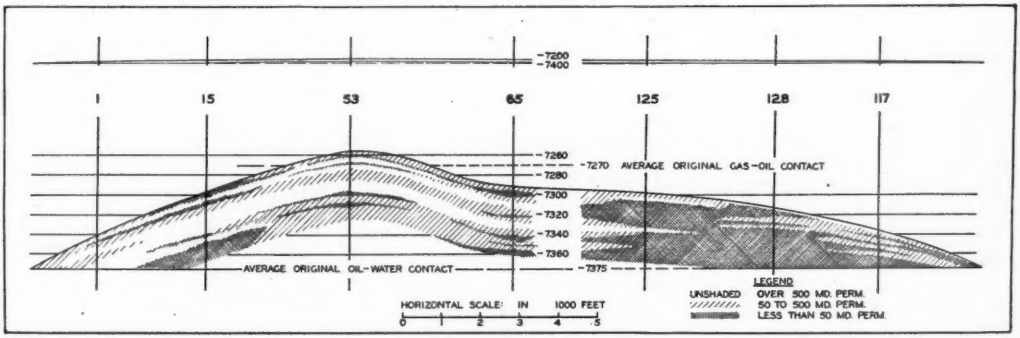

FIG. 2.—General longitudinal section, based on Figure 5.

OIL-IN-PLACE AND ESTIMATED RECOVERY

The productive sand volume of 150,000 acre feet was planimetered from an isopach map drawn on the net productive thickness.

The average porosity of the productive sand for the entire pool, 20.2 per cent, represents planimetered volume from the isovol map, divided by isopach volume. (The isovol map was contoured on values for each well obtained by multiplying the net thickness by the average porosity.)

By applying 1.45 initial formation volume factor,[4] the initial oil-in-place is calculated to be 106,000,000 barrels if 35 per cent connate water is assumed, or 122,000,000 barrels if 25 per cent connate water is assumed.

For a continuation of primary operation, Kaveler[5] shows an estimated ultimate recovery of 34,000,000 barrels (this represents 30 per cent recovery of 113,000,000).

[4] "The Volume under Reservoir Conditions of the Oil and Its Associated Gas from Which Is Derived One Volume of Crude Oil," *Amer. Petrol. Inst.*, Vol. 22, IV (1941).

[5] H. H. Kaveler, "The Schuler Field, Union County, Arkansas," New York Meeting, American Institute of Mining and Metallurgical Engineers, February 15, 1943.

CORE-GRAPH DETAIL

Figure 3 is an example of the core graphs which were constructed primarily for the completion of each well, but which have been of great value in reservoir calculations and are of increasing importance in reconditioning and in pressure-maintenance operation. Table I shows the complete core-analysis record from which the core-data parts of the graph were drawn. The record is that of Schuler unit No. 7, in the northwest part of Figure 1. The top of the Jones sand in this

TABLE I
SCHULER UNIT 7 (PHILLIPS AMANDA NO. 2)
CORE ANALYSIS
(Elevation, 240 feet)

Depth (Feet)	*Permeability (Millidarcys)*		*Porosity (Per Cent)*	*Oil Saturation (Per Cent)*	*Water Saturation (Per Cent)*	*Chloride Content*		*Description*
	Hor.	*Vert.*				*Parts Per Million of Sand Plus Solids*	*Parts Per Million of Water Distilled from Core*	
7,563.0	Top of Jones sand		(7,323 Subsea)					Fine soft sand
7,564.3	180	393						Fine soft sand
64.5			26.2	15.1	58.8	213	2,830	Fine soft sand
65.4	993	1,100	26.1					Fine soft sand
65.7			26.3	15.7	62.5	213	2,560	Fine soft sand
66.3	374	477	26.6					Fine soft sand
66.5			27.7	13.6	58.8	177	2,110	Fine soft sand
67.3	161	105	25.9					Fine soft sand, slightly silty
67.6			25.4	12.5	53.6	248	3,640	Fine soft sand
68.5	0.1*	0.1*	13.2					Hard silty sand
68.7			12.1	11.5	62.9	6,100	189,900	Hard silty sand
69.4	0.1*	0.1*	13.1					Medium hard silty sand
69.6			13.0	14.5	88.2	6,600	135,000	Medium hard silty sand
70.2	0.1*	0.1*	16.1					Hard silty sand
70.4			17.2	6.2	54.6	5,180	122,200	Hard silty sand
71.3	100	13.4	24.3					Fine soft sand
71.7			24.9	6.2	59.6	390	5,290	Fine soft sand
72.8	5.9	1.5						Hard silty sand
72.6			25.6	7.7	70.5	319	3,520	Fine soft sand
73.5	261	210						Fine soft sand
73.7			25.2	8.2	62.0	355	4,560	Fine soft sand
74.6	423	501						Medium soft sand
74.9			24.8	13.1	54.9	461	6,850	Medium soft sand
75.4	349	730						Medium soft sand
75.6			25.1	11.6	55.1	497	7,207	Medium soft sand
76.3	368	472						Fine soft sand
76.5			26.8	11.1	66.6	319	3,510	Fine soft sand
(Cored 15 feet, recovered 12.6 feet)								
7,579.3	385	426						
79.5			25.1	13.8	48.6	390	6,410	Fine soft sand
80.2	494	657						
80.4			26.7	14.1	35.4	248	5,210	Fine soft sand
81.1	461	334						
81.3			25.0	12.4	42.6	461	8,670	Fine soft sand
82.3	432	526						
82.5			26.6	11.0	42.0	248	4,390	Fine soft sand
83.2	504	619						
83.4			26.4	12.5	40.5	284	5,260	Fine soft sand
84.3	636	549						Fine medium soft sand
84.5			26.6	10.3	38.9	355	6,750	Fine medium soft sand
85.1	336	290						Fine medium soft sand
85.3			25.5	12.8	41.0	319	6,139	Fine medium soft sand
(Cored 10 feet, recovered 7 feet)								
7,589.3	374	418						Fine medium soft sand
89.5			24.2	13.8	39.5	284	6,060	Fine medium soft sand
90.3	58	39						
90.5			23.8	7.4	42.8	284	5,680	Fine medium soft sand
91.3	414	351						Fine medium soft sand
91.5			26.6	12.8	34.4	284	6,120	Fine medium soft sand
92.1	606	505						Fine medium soft sand
92.3			25.2	10.2	41.5	177	3,400	Fine medium soft sand
93.3	593	540						Fine medium soft sand
93.5			26.3	12.2	37.8	142	2,820	Fine medium soft sand
94.2	846	317						Fine medium soft sand
94.4			25.4	12.1	39.1	142	2,870	Fine medium soft sand

TABLE I—*Continued*

Depth (Feet)	Permeability		Porosity (Per Cent)	Oil Saturation (Per Cent)	Water Saturation (Per Cent)	Chloride Content		Description
	Hor. (Millidarcys)	Vert. (Millidarcys)				Parts Per Million of Sand Plus Solids	Parts Per Million of Water Distilled from Core	
95.1	414	318						Fine medium soft sand
95.3			24.1	13.1	37.5	213	4,810	Fine medium soft sand
96.0	198	117						Fine medium soft sand
96.2			26.5	11.1	36.7	248	5.040	Fine medium soft sand
97.0	232	367						Fine medium soft sand
97.2			24.2	14.0	35.2	248	5,940	Fine medium soft sand
97.7	330	147						Fine medium soft sand
97.9			21.2	12.5	45.2	142	3,140	Fine medium soft sand
98.9	187	233						Fine medium soft sand
99.2			17.4	6.8	51.7	4,260	104,800	Hard fine silty sand
7,600.0	268	0.1*						Hard fine silty sand
00.1			18.2	9.6	50.0	3,400	81,900	Hard fine silty sand
(Cored 14 feet, recovered 12 feet, 1 foot made by reamer)								
7,604.3	1,120	1,030						Fine soft sand
04.5			24.8	16.6	52.7	426	6,560	Fine soft sand
05.1	0.1*	0.1*						Very hard silty sand
05.3			9.1	3.7	63.4	2,230	94,400	Very hard silty sand, with calcareous streaks
06.3	199	65						Medium hard fine sand
06.5			23.6	10.0	38.2	248	5,640	Medium hard fine sand
07.3	524	190						Medium hard fine sand
07.8			29.2	7.8	26.4	355	8,710	Medium hard fine sand
08.3	0.1*	0.1*						Hard silty sand
08.5			18.0	12.8	44.2	1,772	49,000	Hard silty sand
09.3	543	244						Fine medium hard sand
09.5			24.2	10.5	37.3	1,276	28,700	Fine medium hard sand
10.8	0.1*	0.1*						Hard silty sand, with a few thin shale streaks
11.0			5.4	36.5	40.0	1,240	146,900	Hard silty sand, with a few thin shale streaks
12.0	0.1*	0.1*						
7,611.8			7.6	16.2	42.8	1,453	111,000	Hard silty sand, with a few thin shale streaks
12.5	0.1*	0.1*						Very hard sandy shale
12.7			Discarded					Very hard sandy shale
14.5	0.1*	0.1*						Gray shale
14.7			Discarded					Gray shale
15.7	0.1*	0.1*						Very hard sandy shale
15.9			10.9	15.1	40.5	2,161	117,000	Very hand sandy shale
16.7	0.1*	0.1*						Gray shale
16.9			Discarded					Gray shale
18.2			16.2	9.8	34.0	674	27,600	Hard medium fine sand
18.4	62	44						Hard medium fine sand
(Cored 15 feet, recovered 14.3)								
7,619.6	23	0.1*						Medium hard medium fine sand
19.8			15.1	12.5	40.4	2,692	100,500	Medium hard medium fine sand
20.4	297	172						Medium hard medium fine sand
20.6			20.6	11.2	35.0	284	8,390	Medium hard medium fine sand
21.3	212	37						Medium hard medium fine sand
21.5			19.5	13.8	34.5	461	14,850	Medium hard medium fine sand
22.1	169	0.1*						Medium hard medium fine sand
22.3			18.6	15.0	27.8	355	14,930	Medium hard medium fine sand
23.3	393	119						Hard fine sand, slightly silty, gray shale 0.2 feet
23.5			17.6	12.7	35.6	461	16,300	Hard fine sand, slightly silty, gray shale 0.2 feet
24.4	73	1.5						Hard fine sand, slightly shaly
24.6			19.1	14.6	31.5	142	5,070	Hard fine sand, slightly shaly
25.4	433	336						Hard fine sand, some shale streaks
25.6			19.7	10.8	33.3	142	4,640	Hard fine sand, some shale streaks
26.4	66	45						Hard fine sand, some shale streaks
26.6			15.3	7.8	34.1	248	10,750	Hard fine sand, some shale streaks
27.6	0.1*	0.1*						
27.7			8.8	18.5	37.5	1,910	142,000	Very hard fine asphaltic sand
28.2	0.1*	0.1*						Very hard fine asphaltic sand
28.4			14.6	10.0	41.3	4,110	156,000	Hard fine asphaltic sand
29.2	1.8	—						Hard fine asphaltic sand, gray shale—0.3 feet
29.4			12.5	25.0	37.5	2,940	146,000	Hard fine asphaltic sand
7,630.4	13	1.2						Hard fine asphaltic sand
30.6			16.3	23.1	34.6	3,580	147,800	Hard fine asphaltic sand
31.4	25	18						Hard fine asphaltic sand
31.6			16.1	29.4	28.8	2,760	133,300	Hard fine asphaltic sand

* Having permeability less than 1 millidarcy.

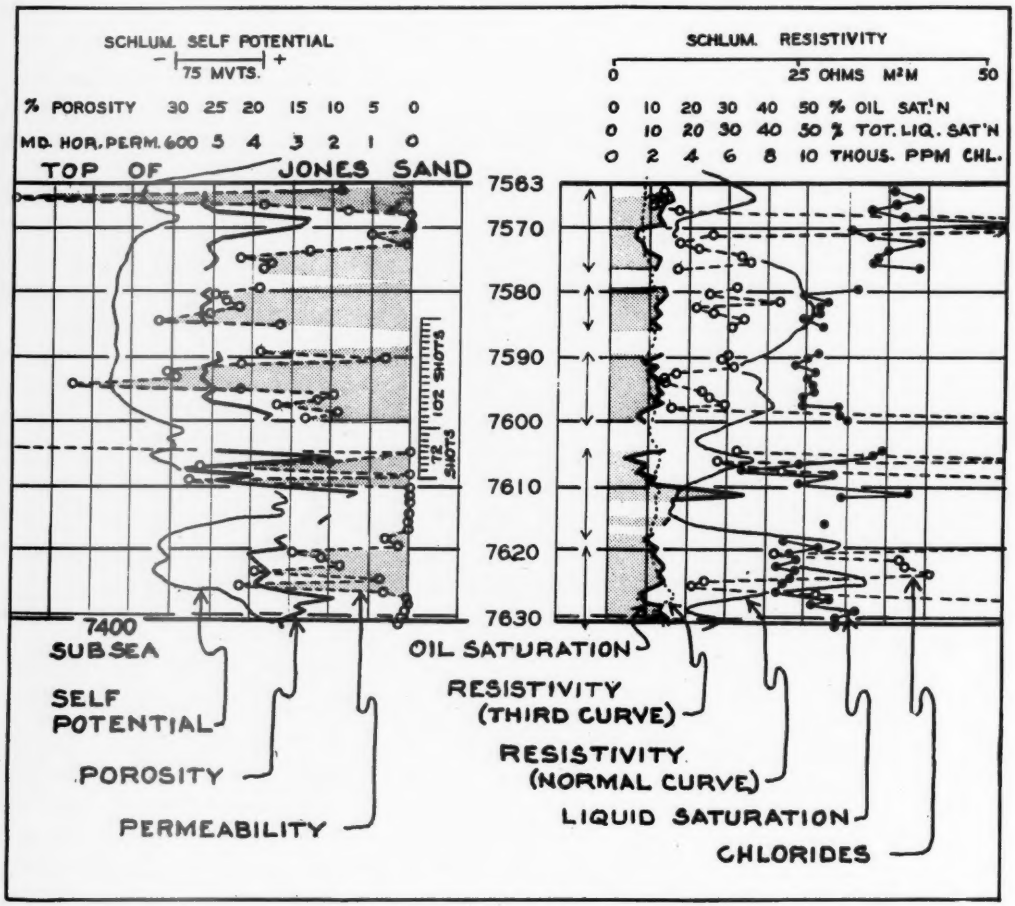

FIG. 3.—Core graph, Schuler Unit No. 7.

well is 7,323 feet subsea, 72 feet below the highest well and 39 feet above the lowest well in the field. This is a typical core record; five cores were taken, covering an interval of 70 feet from 7,564 to 7,634 feet; total core recovery was 59.3 feet.

In addition to the core-analysis data, comprising per cent porosity, permeability parallel with bedding, oil saturation, total-liquid saturation, and chloride content, the graph also includes the corresponding electric-log self-potential and resistivity diagrams.

It may be useful to recall: porosity is a measure of the capacity of the formation to *contain* fluid, and represents the summation of all the interstices without regard to size, shape, or interconnections; *permeability* is a measure of the fluid *transmitting* capacity of the formation, and depends on interconnected pores resulting from grain size and distribution.

Near the top of the sand at 7,565.4, permeability of 993 millidarcys corresponds with porosity of 26.1 per cent; at 7,567.3, permeability of 161 millidarcys corresponds with 25.9 per cent; at 7,568.5, permeability of less than 1 millidarcy corresponds with 13.2 per cent porosity. Thus in 3 feet, while porosity has decreased by half, permeability has decreased more than 1,000 times.

In this same 3-foot interval, because of variation in degree of flushing by the drilling fluid, chloride content increases from 2,560 parts per million to 189,900 parts per million (chloride content here represents parts of chlorides per million parts of water distilled from the core). Apparent evidence of the absence of flushing is the close agreement of the high chloride content with that of the brine occurring with Jones sand oil production. The average of six analyses is 141,134 parts per million of brine which may be converted to 182,300 parts per million of distilled water.

In the lower part of the graph, a 6-foot shaly section, 7,611–7,616 feet, has porosities ranging from 5.4 to 10.9 and permeabilities all less than 1 millidarcy; the 6-foot sand section just below, at 7,620–7,626 feet has porosities ranging from 17.6 to 20.6 and permeability ranging from 73 to 433 millidarcys. Chloride content of 111,000 to 146,900 parts per million in the shaly section contrasts with 4,640 to 16,300 parts per million in the sand section.

The oil saturation recorded by the graph, ranging from 11 to 15 per cent in the productive sand, is not a measure of the oil saturation in the reservoir, but represents only the residual oil after a production cycle by gas expansion plus more or less effective water flooding.

Here the electric-log self-potential diagram is apparently more closely correlative with porosity than with permeability. This indicates that, of the two causes for this diagram, electro-filtration and electro-osmosis, the latter is predominant; that is, the electromotive force generated by the two electrolytes, the fresh water of the drilling mud, and the salt water of the formation.

Figure 4 shows two wells, Schuler unit Nos. 53 and 75, situated above the highest structure contour (Fig. 1). Average gas-oil contact at 7,270 feet subsea is marked by a change from a porous zone with no oil saturation to a porous zone

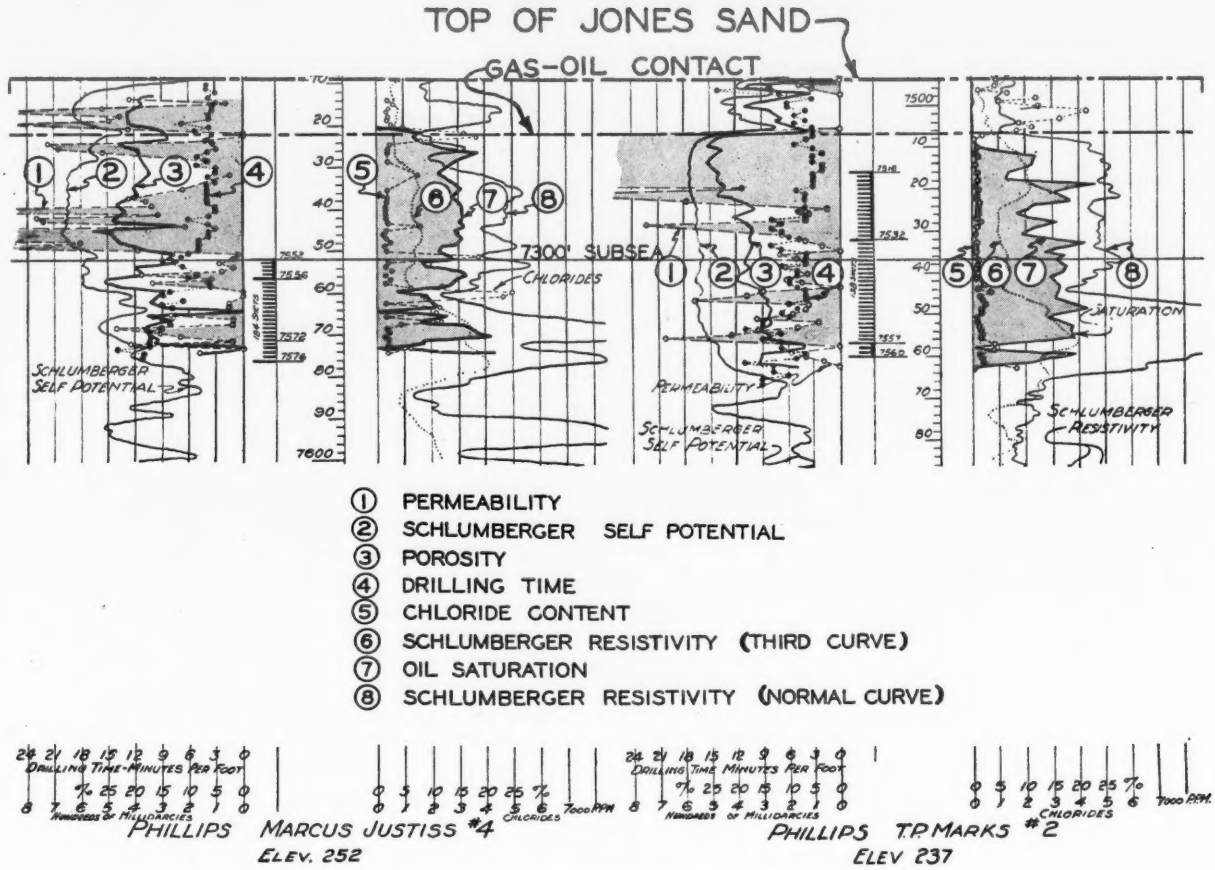

FIG. 4.—Core graphs, Schuler unit Nos. 53 and 75.

showing oil saturation. The gas-cap zone is also in some places highly permeable as in the case of the well on the left. The electric-log self-potential follows porosity very consistently in these two graphs; a particularly interesting example is seen in the gas-cap zone of the well on the right; permeability continues less than 1 millidarcy while porosity increases to a peak, with the self-potential following the porosity peak.

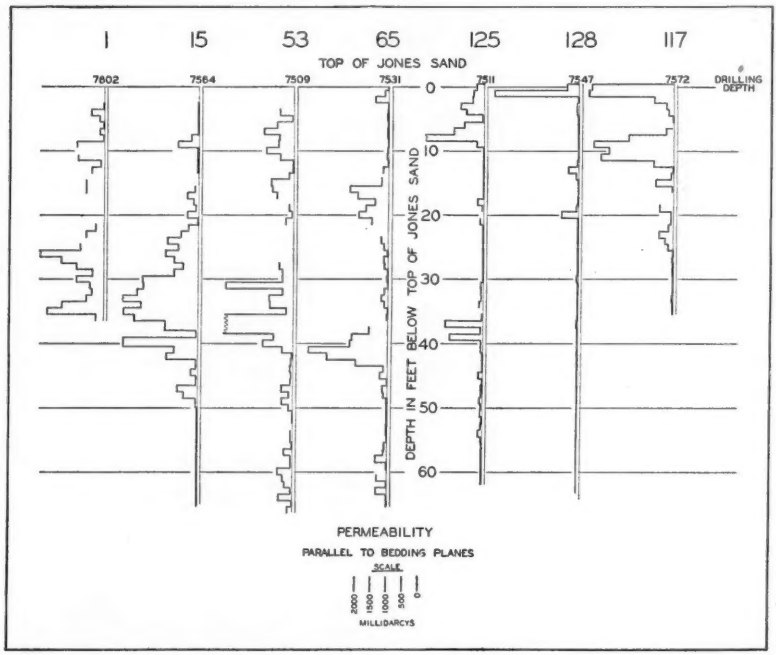

FIG. 5.—Longitudinal Section *AA'*, showing permeability profiles.

The graph on the right furnishes another useful comparison of relative porosity and permeability variation. In the highly permeable zone, 7,510–7,517 feet porosity ranges from 22.3 to 25.5 per cent and permeability from 1,200 to 4,800 millidarcys. In the low-permeability zone, 7,500–7,509 feet porosity ranges from 5.0 to 18.5 per cent and permeability is less than one millidarcy. The high-porosity average is only double the low-porosity average, while the high-permeability average is more than 3,000 times the low-permeability average.

This pair of graphs brings out particularly well the lack of correlation between wells in respect to permeability of zones of equivalent stratigraphic position. Above the gas-oil contact, there is high permeability on the left corresponding

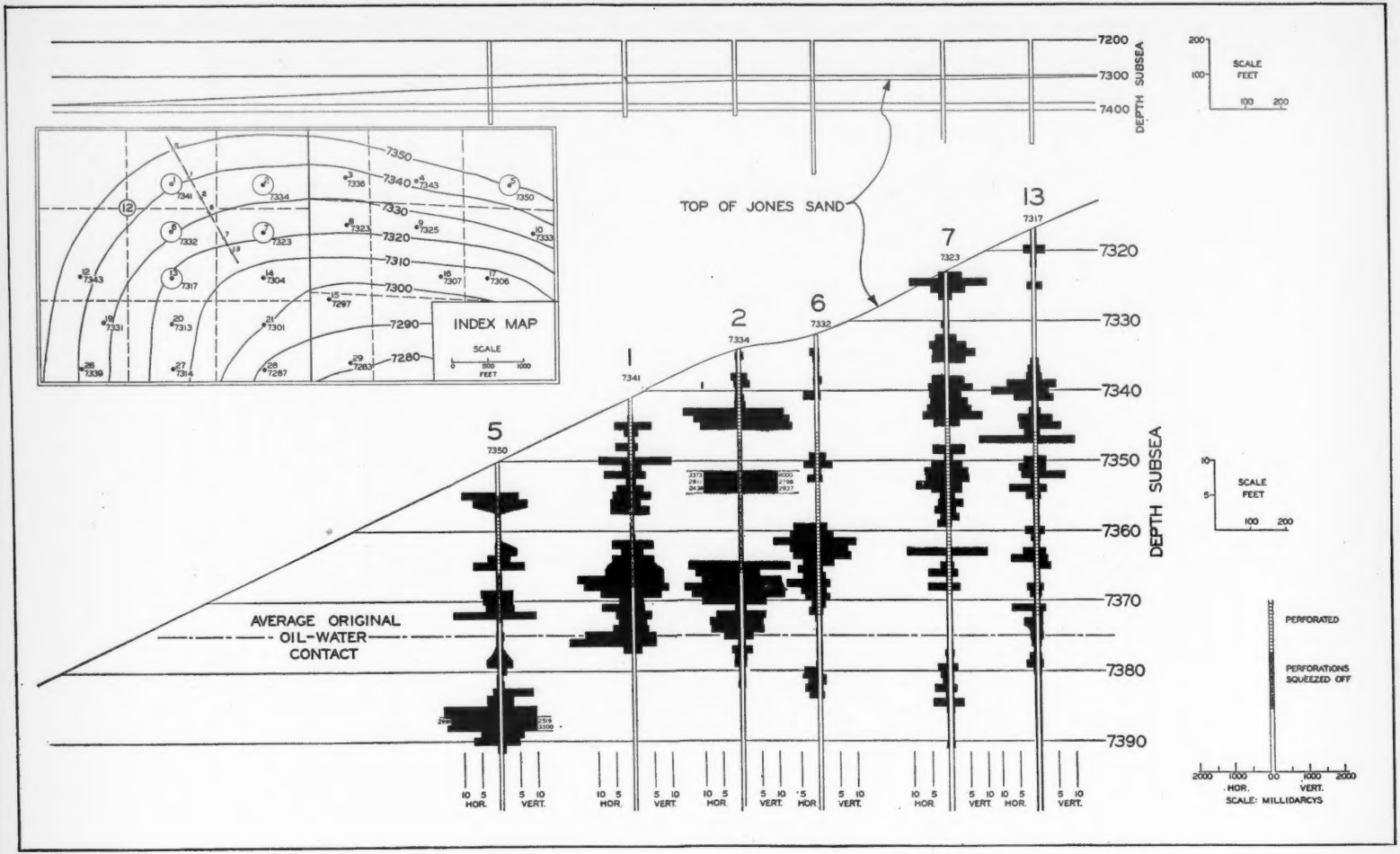

FIG. 6.—Cross section *CC'*, showing permeability profiles.

with low permeability on the right. Between the gas-oil contact and the 7,300-foot subsea line it is seen that the permeability profiles of these two wells are quite different.

PERMEABILITY STUDIES

As the degree of continuity of permeability is probably the most important reservoir factor in the pressure-maintenance program of gas injection, this has been studied in some detail. Three cross sections have been constructed of permeability profiles (Figs. 5, 6, and 8).

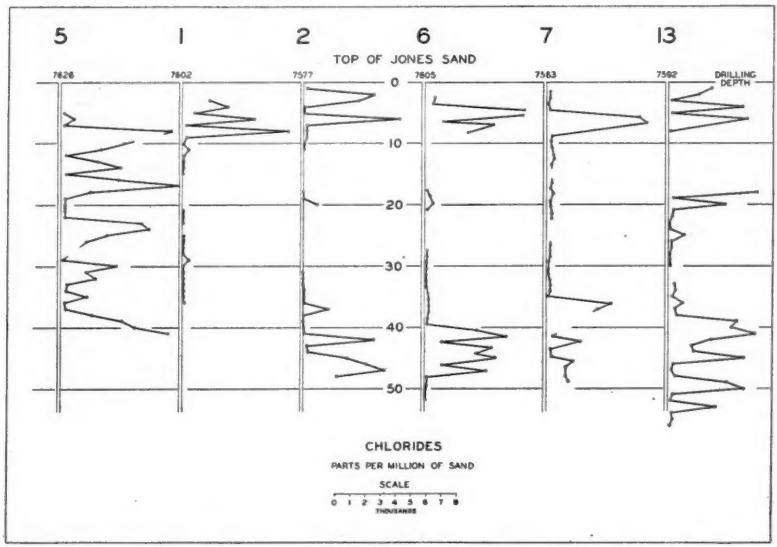

FIG. 7.—Cross section *CC'*, showing chloride profiles.

Figure 5 represents a general longitudinal section from northwest to southeast, shown as *AA'* in Figure 1. The top of the Jones sand is shown as a horizontal line; depths are in feet below the top of the sand. A feature of this cross section is the highly permeable interval between 20 and 40 feet penetration in well No. 15 in the northwest area, gradually thinning until it disappears entirely in the southeast area. Except for such general features, permeable zones are not correlative from well to well.

Figure 6 is a cross section of six wells at the northwest edge, represented by *CC'* in Figure 1. At the top, an outline of the cross section is drawn with the vertical scale made the same as the horizontal. This cross section illustrates the general equality of permeability parallel with the bedding (shown on the left) and permeability perpendicular to the bedding (shown on the right). Average

original oil-water contact is shown. Oil-water contact has been defined[6] as: "The surface in a reservoir above which the predominant saturation (aside from interstitial water) is oil, and below which is water." The order in which these wells first showed substantial water percentages was as they appear in the cross section, updip left to right, indicating that in this local area the predominant direction of water encroachment is parallel with the bedding.

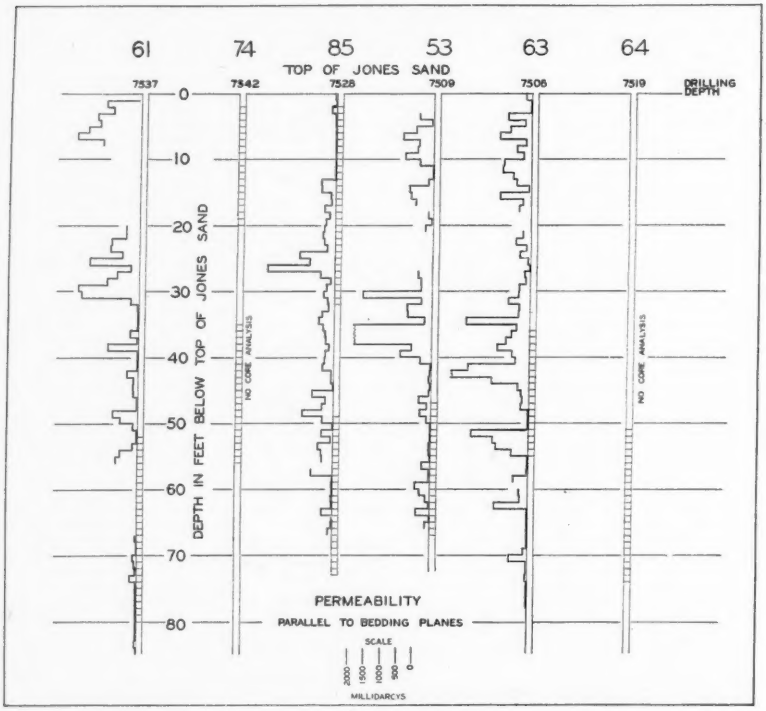

FIG. 8.—Cross section *BB'*, showing permeability profiles.

From these same six wells of Figure 6, Figure 7 shows profiles of chloride content in the same manner as permeability is shown in Figure 5. Low-permeability zones of high-chloride content are most prominent in two positions: within the first 10 feet, and just below 40 feet penetration.

Figure 8 shows permeability profiles for those input wells for which core analyses were made. Perforated intervals are also shown; in the case of wells 74 and 85 the upper interval was perforated just before these wells were converted to input wells; in these two wells gas is being injected directly into the gas cap. The position of the average original gas-oil contact (7,270 feet subsea) in these six input

[6] *Amer. Petrol. Inst.*, Vol. 22, IV (1941).

wells is as follows, reading from left to right: 10, 8, 11, 13, 14, and 5 feet below the top of the Jones sand. This cross section also illustrates the lack of continuity of shaly or silty zones of low permeability, or of zones of high permeability. This is a definite advantage in this gas-cap type of pressure maintenance. Continuous shale or silty partings between permeable zones would cause the injected gas to move parallel with the bedding and restrict its vertical movement; the discontinuous character of such separations in this reservoir provides extremely favorable conditions. The injected gas, instead of finding a short path to the nearest producing well, disperses in various directions and in various planes, resulting in more uniform and effective moving of oil to the well bore.

Figure 2, longitudinal section AA', is an interpretation of permeability conditions throughout the reservoir, based on the actual measured permeabilities in the seven wells of Figure 5. For simplicity, only three divisions of permeability are made: more than 500, 50 to 500, and less than 50 millidarcys.

PRESSURE-MAINTENANCE HISTORY

The six input wells (Figs. 1 and 8) have been returning 26,000,000 cubic feet of gas per day with an input pressure of approximately 1,350 pounds. Percentages of this total taken by each input well are shown for two recent months, September, 1942, and January, 1943. These percentages are given in the order of Figure 8 from left to right.

Well number	61	74	85	53	63	64
September, 1942, per cent	20	19	13	15	11	23
January, 1943, per cent	18	23	16	22	8	13

It is evident that the permeability profile in the well bore does not necessarily reflect the capacity of the reservoir to accept gas through that well bore. It is possible that a well with a comparatively low measured foot-millidarcys permeability may connect with channels of high capacity beyond the well bore so effectively that more gas is accepted by the reservoir through that well than through another well of higher measured foot-millidarcys capacity.

Additional evidence of the absence of direct interconnection between wells appears from the history of No. 52, producing well, as related to No. 53, input well, only 660 feet east (Fig 1). Gas is injected into well 53 through perforations 47–67 feet below the top of the sand; well 52 produces through perforations 55–75 feet below the top of the sand. Producing gas-oil ratios for recent months are available for well 52 combined with well 84; both these wells are direct offsets of input wells and have been producing almost continuously since the beginning of the unitized program. Recent gas-oil ratios in cubic feet per barrel are: 1942, October, 3,447; November, 3,479; December, 3,516; 1943, January, 3,639. In February, 1942, average ratio of these two wells combined with No. 62, also directly offsetting an input well, had reached 3,180 cubic feet per barrel. It appears that in these producing wells, 660 feet distant from input wells, gas-oil ratio increases at a rate not exceeding the expected average rate of increase for the reservoir, as discussed in the following paragraph.

Figure 9 (after Kaveler[5]) shows average reservoir pressure and gas-oil ratio plotted against accumulated oil production. When unitization went into effect, wells with high producing gas-oil ratios were shut in, and the unit allowable was produced from the most efficient wells, about one-third of the total number. In this way the average gas-oil ratio was immediately cut from 2,800 to 1,463 cubic feet per barrel, as is strikingly shown by the graph.

Predicted gas-oil ratio from the beginning of unitized operation, on the assumption 90 per cent of the produced gas is to be returned to the formation, is shown by the smooth-dash line. Actual gas-oil ratio by months for the 2-year period is represented by the full line; this has been subject to considerable variation due to flexibility of operating conditions and also change in allowable, but it

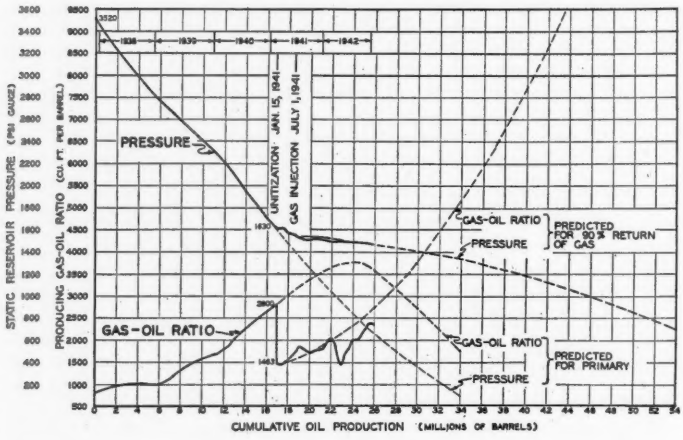

FIG. 9.—Cumulative oil production versus reservoir pressure and gas-oil ratio.

nevertheless displays a definite tendency to follow the predicted trend. Two years after the average gas-oil ratio was reduced one-half by shutting-in wells, the average ratio is still below the 2,800 cubic feet per barrel at which the reservoir was producing before unitization.

In Figure 9 it is seen that unit operation began when pressure had declined from 3,520 pounds to 1,600 pounds, and nearly 17,000,000 barrels or half of the estimated 34,000,000 barrels of primary production had been received. While 9,000,000 barrels of oil have been produced during the unit operation, pressure has declined from 1,609 to 1,469 pounds, a decline of only 140 pounds.

Under unitized gas injection of 90 per cent of the produced gas volume, it was estimated that the ultimate recovery would be approximately 54,000,000 barrels, an increase of approximately 20,000,000 barrels over primary production, even though the secondary operations were not commenced until half of the primary production had already been recovered.

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WELL SPACING—ITS EFFECT ON RECOVERIES AND PROFITS[1]

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Ponca City, Ardmore, and Ponca City, Oklahoma

ABSTRACT

The paper presents a study of the effect of well spacing on recoveries based on factual data from ten different fields. Data on comparative recoveries from the five Woodbine sand fault-line fields of Texas are cited as virtually providing a laboratory demonstration, in that other factors are constant but spacing varies through a relatively wide range. Since the fields are separate, these data can not be discredited on the grounds that the more closely spaced wells obtained their additional recoveries at the expense of the widely spaced ones.

Graphic charts incorporating a well-spacing scale in the form of an inverted diminishing series based on the expression $1/\sqrt{\text{acres per well}}$ are used: (1) to show that the recoveries from the fault-line fields are almost precisely proportional to the reciprocals of the square roots of the respective well spacings expressed in terms of acres per well; (2) to show that the same relationship exists in cases where two different parts of the same field are developed on different spacing patterns; and (3) to study the deviation from that "normal expectancy" with intra-field groups where well density varies erratically within the field.

The hypothesis is advanced that the mathematical relation between well spacing and recoveries is an index of the inherent inefficiency of the well system of oil-field development.

It is also pointed out that arbitrary wide-spacing patterns may make it impossible to develop adequately accumulations against faults or small fields on sharply folded structures. The Crescent field, Oklahoma, is cited as a case in which fully half of the Ordovician production has come from a pay zone which would never have been tapped if the original 40-acre spacing pattern had been adhered to throughout the development of the field.

Attention is also called to the fact that widening the well spacing increases the ratio of dry holes, required to define a field, to producers in the field; and that the effect becomes more serious as field size diminishes.

In the discussion of the effect of well spacing on profits, it is pointed out that most such discussions in recent years have incorporated major fallacies which have served to "load" them heavily in favor of wide spacing. For instance, they have generally assumed that recovery is largely independent of spacing; consequently, they have concluded that the extra cost of additional wells over some arbitrarily selected spacing is all loss. They have also treated costs confined to the producing lease as if they represented the total cost of producing oil, completely ignoring the cost of finding and acquiring such productive leases.

An analysis of a hypothetical field is presented to show all the factors which must be taken into consideration to fairly judge the effect of various spacings on profits.

On the basis of the evidence presented, the following major conclusions are reached.

1. Well spacing does affect the recovery of oil from a reservoir; increased well density results in increased recovery; and within practical limits there is a definite mathematical relationship between the two.

2. Arbitrary wide-spacing regulations impose definite handicaps on the adequate exploitation of small accumulations on sharp folds or against faults, and increase the ratio of dry holes to development.

3. From the standpoint of cost per barrel of crude recovered or of profit per dollar expended, it is not invariably true that the wider of two spacings is the more economical. For a given set of conditions there is a certain spacing which is most economical; and either a closer or a wider spacing involves higher unit costs and lower unit profits.

The effect of well spacing on both recoveries and profits has been a highly controversial subject. The effect on recoveries alone has not been a matter of universal agreement. And under a barrage of propaganda for wide spacing, as an alleged

[1] Manuscript received, November 18, 1943.

[2] Continental Oil Company.

[3] Oil producer, 509 Simpson Building.

[4] Continental Oil Company.

cure for the financial problems created by the nationwide adoption of proration and the subsequent period of declining allowables that followed the discovery of the East Texas field, any calm appraisal of the subject on a strictly scientific basis was virtually impossible.

Now that a persistent decline in the rate of discovery over a period of the past 6 years has substituted the problem of maintaining supplies of oil adequate for our needs for that of declining allowables, it may be possible for the whole question of well spacing to receive consideration on a purely objective basis. The purpose of this paper is to present such a study.

The discussions are intentionally limited to sands and limestone or dolomite reservoirs whose physical characteristics are such that they behave like sands; that is, oil movement is through capillary openings. It is recognized that an accumulation of oil in a true cavern like that at Carlsbad might be drained, within a period of time having some significance in relation to human lifetime, by one properly located well.

Considering the effect of spacing on recoveries, it may be noted that until recent years there was no disposition to question the idea that closer spacing did mean increased recovery from a reservoir as a whole. But with the advent of proration and of various production practices looking toward more efficient utilization of reservoir energy, it has become fashionable to assume that recoveries per acre or per unit volume of "pay" are virtually independent of well spacing.

Glowing pictures of the economies to be effected through wider well spacing nave been predicated on that assumption.

Some arguments have gone even farther and asserted that close spacing, by increasing the difficulties of controlling the utilization of reservoir energy effectively, would actually decrease recoveries under present-day operating practices.

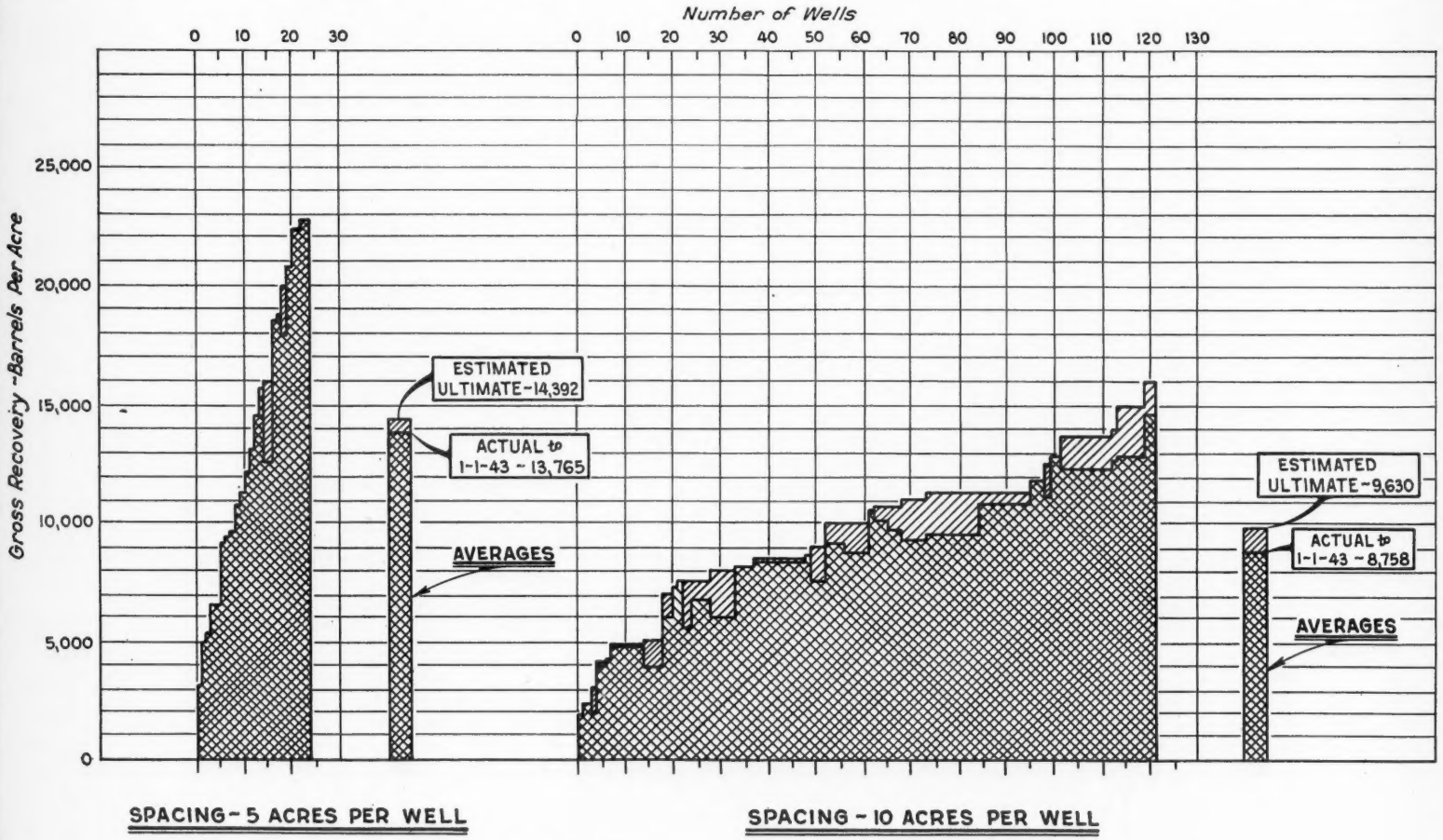
Virtually no valid evidence has been presented in support of such arguments.

The standard procedure in a physical laboratory for studying the relationship between two variables is to hold other factors constant, impose changes in one and observe the effect on the other. Thus if it is desired to determine the temperature-volume relationships for a gas, it is necessary that the pressure be maintained constant while temperature is intentionally varied and the resulting changes in volume recorded. Similarly, to determine pressure-volume relationships, it is essential that temperature be maintained constant during the experiment.

If all the factors were varied simultaneously, the attempt to establish cause and effect relationships would degenerate into mere speculation.

But once those relationships have been determined, it is possible to predict the effect of a combination of variations, by calculating the effect of each individual factor in sequence. The point should be emphasized that it is not permissible to ignore the effect of one variable factor simply because other variables have been introduced.

Obviously the ideal way to determine the effect of well spacing on ultimate recovery would be to apply the principles of laboratory procedure. That

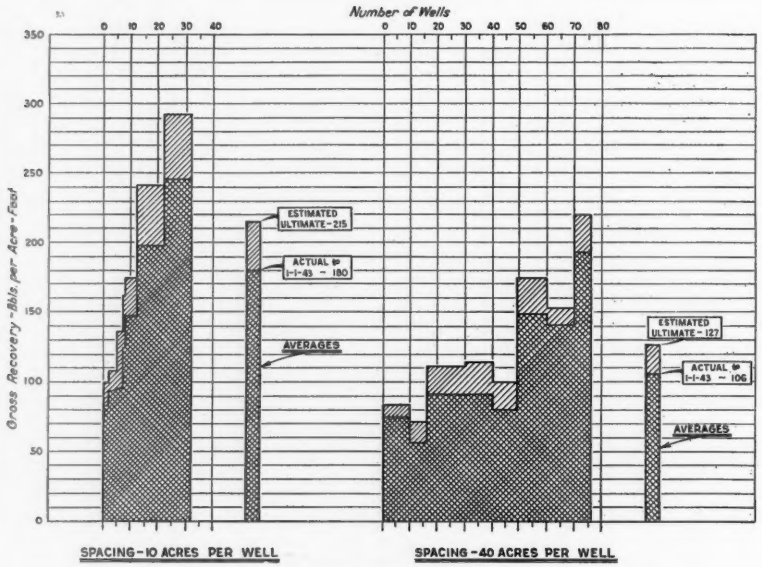


CHASE TOWNSITE POOL - KANSAS

Block diagram showing yields per acre for the areas of 5 and 10 acre well spacing.

FIG. 1

would mean taking a number of fields with identical reservoir characteristics (including porosity, permeability, and type of drive available to force the oil to the hole), equal initial pressure, and oil of the same viscosity and gas content; developing those fields on various well spacings; and then operating them to depletion, using identical production practices in all cases. Under such circumstances, any differences in recoveries would necessarily be attributed to the differences in well spacing.



LUCIEN FIELD - OKLAHOMA

Block diagram showing yields per acre-foot from Simpson sands for the areas of 10 acre spacing (actual average 11.0 acres per well) and 40 acre spacing (actual average 36.4 acres per well) respectively.

In the area of 40 acre spacing wells are grouped in east-west strips ½ mile wide, arranged in order from south to north. Recoveries for 10 acre wells are shown by leases.

FIG. 2

The fact that such procedure has not been followed as a matter of deliberate intent has imposed great difficulties in the way of obtaining evidence which was not open to challenge on some ground. Either the reservoirs were not comparable, depths and pressures were different, production practices were different, or if a group of fields was found which were ideal in every other respect, the well spacing was apt to be identical, thus precluding the development of any useful information.

Differing recoveries from areas of differing spacing in the same field, such as are illustrated in Figures 1 and 2, have been brushed aside as evidence on the grounds that the closely spaced wells simply represent "extra straws in the same glass."

On the other hand, elaborate arguments designed to show the economic waste involved in close spacing have often been based on recovery estimates made in the early life of fields, which the passage of time have shown to be far short of the actual recoveries.

In view of the difficulties cited, figures recently made available by Hill and Guthrie[5] on unit recoveries from the Woodbine sand fault-line fields in Texas are highly significant because they represent a group of fields in which: (1) the producing horizon is the same; (2) structural conditions are essentially the same; (3) the character of the oil is essentially the same; (4) the variation in depths and pressures is slight; (5) all were exploited in the same manner; that is, rapid development and wide open flow; (6) all were subject to natural water drive; (7) all are so nearly depleted that there is no chance for errors in the estimates of ultimate recovery to have any appreciable effect on the results; and (8) the average well spacing varies through a relatively wide range among the fields.

In other words, these fields provide the equivalent of a laboratory demonstration.

The essential data concerning them are presented in Table I. They are arranged in the order of the well density.

TABLE I

DATA ON MEXIA-POWELL FAULT-LINE FIELDS, TEXAS

	Currie	*Mexia (Fault Leases)*	*Powell*[1]	*Richland*	*Wortham*
Producing acres	435	1,820	2,600	234	760
Number wells	75	391	741	99	354
Spacing: acres per well	5.8	4.7	3.5	2.4	2.2
Pay thickness (feet)	20.9	56.9	46.5	20.1	24.8
Pay volume (acre feet)	9,092	103,543	120,813	4,701	18,868
Production to 1-1-'42 (barrels)	6,645,460	85,700,000[2]	109,972,041	6,398,020	22,741,106
Est. ultimate production	7,000,000	89,500,000	113,500,000	6,500,000	23,500,000
Est. ultimate recovery					
Barrels per acre	16,092	49,179	43,654	27,771	30,921
Barrels per acre feet	770	864	939	1,383	1,245
Percentage[3]	43.6	48.9	53.2	78.3	70.5

[1] Includes Woodbine sand production only.
[2] Approximate.
[3] Based on estimated original oil content of 1,766 barrels per acre feet.

It is evident that the unit recoveries from the more closely drilled fields are greater than from the less densely drilled ones. In fact, the recoveries line up in exactly the order of well density except for the two most closely drilled, in which instance the difference in density amounts to only 0.2 acre per well.

If recoveries under different spacings are related to the average distance the oil has to move to reach a well as suggested by Cutler, then it would be expected

[5] H. B. Hill and R. K. Guthrie, "Analysis of Oil Production in the Near-Depleted Mexia-Powell Fault-Line Fields of Texas," *U. S. Bur. Mines R.I. 3712* (1943).

that they should be proportional to the reciprocal of the square root of the area attributable to each well. Table II shows that the ratio of the two is almost constant for this group of fields.

TABLE II

RATIOS—UNIT RECOVERIES TO RECIPROCAL OF SQUARE ROOT OF SPACING

Field	*Spacing (Acres per Well)*	*Recovery (Bbls. per Acre Foot)*	*Reciprocal of Sq. Root of Acres per Well*	*Ratio Factor*
Currie	5.8	770	0.412	1870
Mexia	4.7	864	0.460	1880
Powell	3.5	939	0.535	1750
Richland	2.4	1,383	0.644	2150
Wortham	2.2	1,245	0.675	1850

This suggests the possibility of utilizing a graphic chart, in which recoveries per acre foot of "pay" and the reciprocal of the square root of the acres per well are used as the coördinates, to show that mathematical relationship. Figure 3 presents such a chart, on which the points for the Texas fault-line fields are plotted.

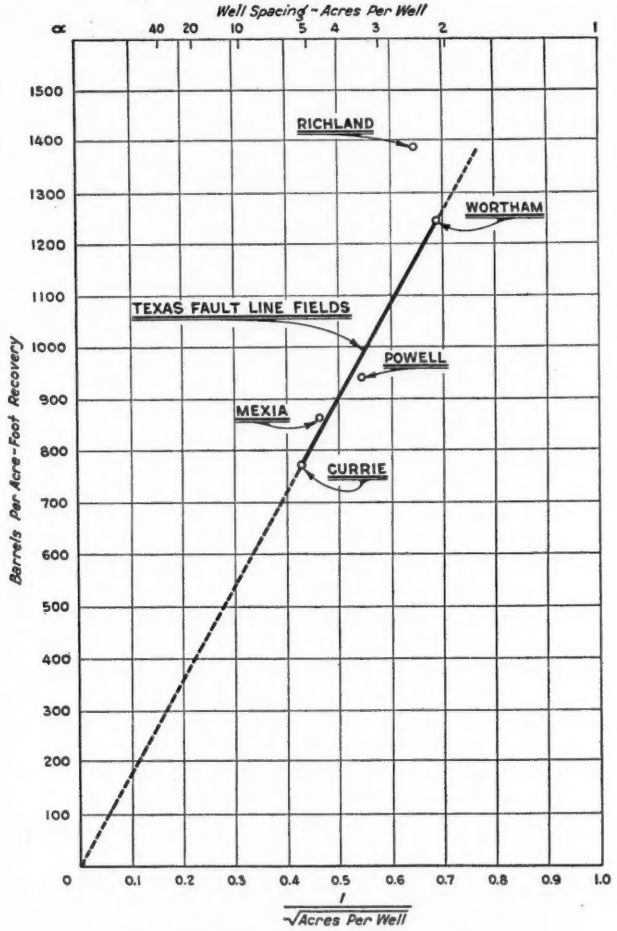
The data for the Wortham, Mexia, and Currie fields fall almost in a straight line, the projection of which passes through the zero point of the two scales. The Powell field point falls only slightly below the line. Only the Richland field point lies appreciably out of line. When the difficulties of determining pay sand volumes precisely and the possibilities for variations in the reservoir rock itself are considered, these data may be regarded as practically perfect evidence of the suspected straight-line relationship.

The importance of these data in their bearing on the problem can hardly be overemphasized, since they probably represent the most conclusive evidence that has been, or is likely to be, assembled as to the exact effect of variation in well spacing alone on unit recoveries.

The meaning of the relationship shown by the graphic chart may be made clear with the aid of the Well Spacing-Acres Per Well scale drawn at the top of the chart. The unit values on this scale represent an inverted diminishing series approaching the zero of the horizontal scale as the spacing approaches infinity. Then, if a straight line passing through the zero point of the chart represents all the variations in recovery from a given reservoir, or from identical reservoirs, for all possible variations in well spacing, other factors being equal, it means that as well spacing increases, unit recoveries decrease in inverse ratio to the square root of the spacing as expressed in terms of acres per well, and that as the spacing approaches infinity the unit recovery approaches zero.

The conclusive demonstration furnished by these data from separate fields that well spacing, even with densities below 6 acres per well, does affect recoveries in accordance with a definite mathematical relationship, makes a huge volume of supporting evidence based on different spacings in the same field admissible.

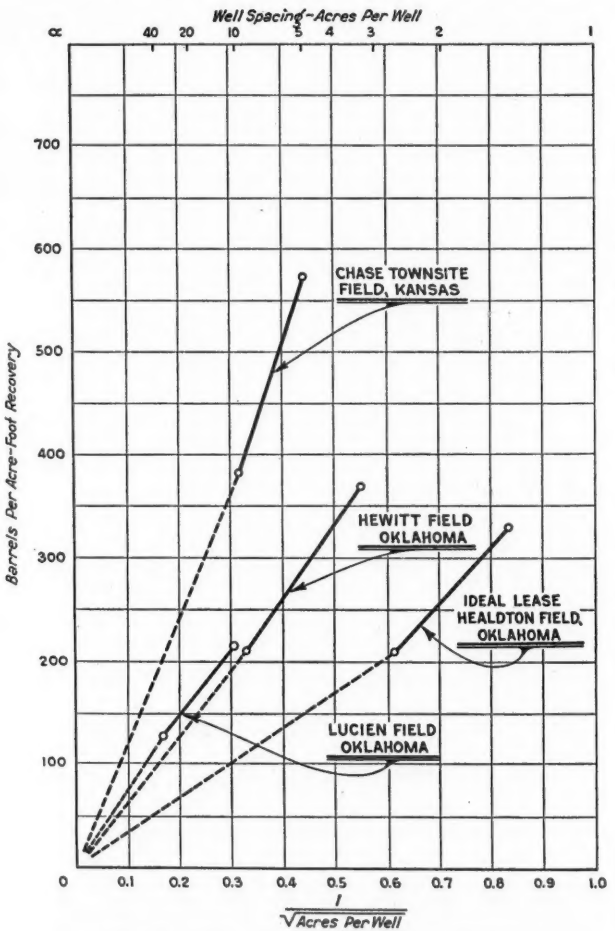
A number of such cases are shown on a second chart (Fig. 4) and following charts.



WELL SPACING - RECOVERY CHART

Illustrating the relation between well spacing and recovery in certain specific instances.

FIG. 3



WELL SPACING - RECOVERY CHART

Illustrating the relation between well spacing and recovery in certain specific instances.

FIG. 4

TABLE III

SUMMARY OF INTRA-FIELR DATA USED IN WELL SPACING—RECOVERY CHART

Field	Producing Wells	Productive Acres	Density (Acres per Well)	Average Sand Thickness	Acre Feet of "Pay"	Barrels Produced 1-1-'43	Barrels Estimated Ultimate Production	Cumulative Recovery		Est. Ultimate Recovery	
								Barrels per Acre	Barrels per Acre Ft.	Barrels per Acre	Barrels per Acre Ft.
Chase Townsite	25	125	5	est. 25	3,125	1,720,672	1,799,038	13,765	549	14,392	575
	121	1,210	10	est. 25	30,250	10,596,912	11,749.906	8,758	350	9,630	385
Lucien‡	32	354	11.0	125	44,554	8,021,564	9,620,000	22,659	180	27,175	215
	76	2,770	36.4	71	196,204	20,814,819	24,585,000	7,515	106	8,875	127
Hewitt	612	2,020	3.3	104	210,080	73,669,400	77,900,000	36,470	350	38,564	370
	82	790	9.6	97	76,630	15,049,500	16,070,000	19,050	196	20,341	210
Mexia	264	873	3.3	58.6	51,189	54,209,410	56,500,000	62,067	1,059	64,690	1,104
	133	579	4.3	43.2	24,994	20,999,368	22,000,000	36,120	840	38,029	880
	127	947	7.45	55.3	52,354	30,637,798	33,000,000	32,370	585	34,865	630
Wortham	76	137	1.8	19.8	2,713		4,707,250			34,359	1,735
	134	257	1.9	27.3	7,016		10,721,449			41,718	1,528
	80	177	2.2	25.9	4,584		5,018,514			28,353	1,095
	64	189	3.0	24.1	4,555	*	3,052,787	*	*	16,152	670
Currie	41	190	4.65	22.2	4,219	3,978,517	*	20.954	943	*	
	17	163	7.18	16.4	2.689	1,497,773		9,134	557		
	8	76.8	9.6	21.1	1,622	749,027		9.727	461		
Richland	58	124.9	2.15	20.9	2,618	3,868,782	3,970,450	30,869	1,477	31,789	1,517
	41	109.1	2.66	19.1	2,083.8	2,529,550	2,529,550	23,186	1,214	23,186	1,214
Healdton											
Ideal Scoggins lease											
Original development (1913–21)	9	25	2.8	95	2,375		503,500†			20,140	212
Additional development (1928–41)	17	—	1.5				783,750†			31,350	330
Additional recovery Attributed to denser spacing and gas injection							280,250			11,210	118

* Data not available.

† Calculations based on study of decline curve.

‡ Six leases including 11 wells in E. ½ Sec. 33, T. 20 N., R. 2 W.; NW. ¼ Sec. 34, T. 20 N., R. 2 W., and NW. ¼ Sec. 3, T. 19 N., R. 2 W., are not represented on chart. Production data were not available for the two wells in the NW. ¼ Sec. 3. The other leases were excluded because of unsegregated Layton sand production.

Lucien field, Oklahoma.—The Lucien field data (Fig. 4) are of particular interest since the initial development was undertaken as a unit operation under proration and the greater part of the field was developed with a spacing of 40 acres per well, with the avowed purpose of making the field a model of economical development and efficient operation.

Several years later a south extension was developed on a minor dome at the south end of the major structural "high." It was largely developed on a 10-acre spacing pattern. Both areas produce from both the First and Second "Wilcox" sands (Ordovician).

Production from the first and second sands has not been segregated, but the productive parts of the two sands in this field appear to be practically identical in character.

It is noteworthy that the line joining the 40-acre and 10-acre recovery points, if projected, passes only slightly above the zero point of the chart. Or, from another viewpoint, the recovery from the 10-acre wells is slightly less than would have been indicated by a line from the zero point to the 40-acre datum.

The specific figures used are set up in Table III.

Hewitt field, Oklahoma.—The data for the Hewitt field (Fig. 4) furnish another nearly perfect confirmation of the proposition that recovery is inversely proportional to the square root of the well density expressed in acres per well. The two points respectively represent an area of 790 acres in the north end of the field with a spacing of 9.6 acres per well and the remainder of the field with an average spacing of 3.3 acres per well.

The economic importance of close spacing in this instance is indicated by the fact that 32,000,000 barrels of oil must be credited to the effect of close spacing. That is, it represents the additional oil recovered to date from the closely spaced part of the field beyond the unit recovery established for the widely spaced part.

Ideal lease, Healdton field, Oklahoma.—The data for the Ideal Oil and Gas Company and 32nd Oil and Gas Company's Scoggins lease in Sec. 32, T. 3 S., R. 3 W. (Fig. 4), presents a different situation from those previously discussed. In this instance, one point represents the estimated ultimate recovery from 9 wells drilled during the period 1914–20 with a spacing of 2.8 acres per well, while the other represents the estimated ultimate recovery from 17 wells in the same area, including 8 drilled during the period 1936–41, bringing the spacing to 1.5 acres per well. Contemporaneous with the additional drilling, some repressuring with gas was undertaken. This probably accounts for the fact that the indicated increase in recovery for the closer spacing is greater than the normal expectancy.

This is merely one instance out of the many which might be cited from the Healdton field, where production history of 30 years has conclusively demonstrated the advantages of close spacing.

Chase Townsite pool, Kansas.—The Chase townsite pool (Fig. 4) presents a case somewhat like that of the Hewitt field, in that the townsite area in the north

TABLE IV

"WILCOX" SAND RECOVERIES, OKLAHOMA CITY FIELD

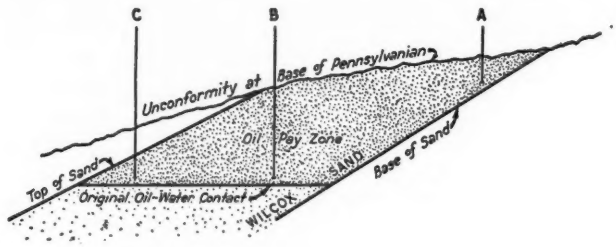
Spacing Interval	*Quarter Section*	*Total Number Wells*	*Number Effective Acres*	*Density Acres/Well*	*Number Acre Feet "Pay"*	*Barrels Cumulative 6-1-'43*	*Estimated Barrels Ultimate*	*Barrels per Acre Foot Ultimate*
0–4 Acres/well								
	SW. 14–12 N.–3 W.	1	1	1.0	113	174,878	220,000	1,946*
	SE. 34	44	160	3.6	30,345	42,544,627	50,000,000	1,647
	NW. 2–11 N.–3 W.	49	150	3.1	10,213	25,626,705	25,800,000	2,526
	NW. 10	42	160	3.8	32,302	20,449,832	23,450,000	725
	SE. 15	24	83	3.5	4,790	8,758,757	9,100,000	1,900
	SE. 22	55	155	2.8	16,220	14,341,736	14,920,000	920
4–8 Acres/well								
	SE. 15–12 N.–3 W.	18	137	7.6	25,130	2,187,178	2,500,000	100
	NE. 22	31	160	5.2	33,683	8,508,908	9,100,000	270
	NW. 23	10	42	4.2	7,246	5,410.564	8,300,000	1,145
	SE. 22	32	160	5.0	35,251	21,723,131	23,875,000	677
	SW. 23	24	107	4.5	21,038	16,062,764	19,200,000	912
	NW. 26	13	57	4.4	3,612	2,011,500	2,100.000	581
	SE. 27	26	160	6.2	25,141	12,394,687	15,350,000	610
	NE. 34	30	160	5.3	28,063	21,239,403	26,300,000	937
	NW. 3–11 N.–3 W.	30	156	5.2	27,428	18,356,317	19,400,000	700
	NE. 3	28	157	5.6	23,065	38,802.732	42,640,000	1,848
	SE. 3	25	156	6.2	13,162	8,628,255	8,925,000	678
	SW. 2	9	53	5.9	1,615	881,155	881,155	545
	NE. 10	27	152	5.6	14,418	17,104,989	18,150,000	1,258
	SW. 10	25	134	5.4	21,648	9,650,428	12,100,000	558
	SE. 10	15	111	7.4	10,850	9,075,989	9,360,000	862
	NE. 22	15	105	7.0	3,830	2,771,736	3,010,000	785
8–12 Acres/well								
	SW. 22–12 N.–3 W.	20	160	8.0	24,170	6,157,837	9,300,000	384
	NW. 27	14	158	11.2	25,401	8,073,222	10,500,000	411
	NE. 27	18	160	8.9	22.886	12,122,655	14,425.000	630
	NW. 34	16	138	8.6	18,572	3,565,941	7,000,000	376
	SW./4 34	20	160	8.0	25,737	9,980,218	12,100,000	470
	SW. 35	12	128	10.6	9,174	3,933,463	4,160,000	453
	SW. 3–11 N.–3 W.	20	160	8.0	28,327	7,708.619	8,375,000	295
	NW. 15	13	145	11.1	20,576	7,017.875	7,950,000	386
	NE. 15	14	120	8.6	14,535	7,337,902	8,425,000	579
	SW. 15	16	151	9.4	16,742	5,438,865	7,050,000	421
	SW. 22	15	157	10.5	15,033	7,001,987	7,500,000	498
	NE. 27	14	147	10.5	19,691	5,374,148	6,060,000	307
12–16 Acres/well								
	SW. 27–12 N.–3 W.	8	117	14.6	13,508	2,241,551	4,100,000	303
	NW. 35	5	64	12.8	3,002	1,389,940	2,100,000	700
	Total South End Area—SE. 27, NW., SW. & SE. 26; NW., NE., SE. 35; S./2 25; All Sec. 36; NW., SW., & SE. 31–11 N.–2 W.; SW. 32–11–2; N./2 6–10 N.–2 W.	103	1,306	12.6	143,303	37,807,611	45,750,000	320
Over 16 Acres/well								
	NW. 22–11 N.–3 W.	6	100	16.7	5,361	1,029,187	1,190,000	221
	SW. 23	2	35	17.5	1,412	362,733	362,733	256
	SE. 4	2	64	32.0	4,022	70,000±	70,000±	17*
	NW. 27	1	56	56.0	3,026	95,000	95,000	31*
	NW. 22–12 N.–3 W.	2	145	70.3	12,862	164,228	200,000	16*
Undrilled quarter sections								
	NE. 15–12 N.–3 W.		105		8,112			
	SW. 15		98		6,047			
	NE. 21		7		74			
	SE. 21		51		1,489			
	NE. 28		42		1,789			
	NE. 33		8		149			
	SE. 33		56		2,867			
	NE. 4–11 N.–3 W.		108		9,363			
	NE. 9		65		4,301			
	SE. 9		37		1,678			
	NE. 16		16		421			
	SE. 16		28		983			
	SE. 27				2,239			

* Sand volumes attributed to these wells probably in error.

end of the field was developed on a spacing averaging 5 acres per well as compared with 10-acre spacing in the remainder of the field. The recoveries per acre, actual and estimated ultimate, are shown in Table IV.

So far as it can be determined, the average thickness of pay in the two areas is approximately the same. Precise computation of the actual volumes of "pay" in this porous dolomite are impossible. The unit recoveries plotted on the chart were computed on the basis of an average of 25 feet of pay, which is approximately the average thickness of Arbuckle limestone present above the original water level. This simply serves to give figures which fall within the range of the chart. The resulting comparison is precise for acre yields and is believed to be relatively fair for unit volume recoveries.

The increase in recovery per acre for the closer spacing is obvious. The recovery for the 5-acre wells is somewhat higher than would have been predicted on the



OKLHOMA CITY FIELD -"WILCOX" SAND

Diagramatic cross section of oil pay zone normal to the strike of the beds.

FIG. 5

basis of a line through the zero point and the 10-acre recovery point; but the agreement is close enough to confirm substantially that mathematical relationship.

"Wilcox" sand, Oklahoma City field.—The comparisons made thus far have been based on separate fields, or on separate sections of the same field developed on distinctly different spacing patterns.

The data for the "Wilcox" sand in the Oklahoma City field (Table IV), provide an opportunity for a study of the effects of erratically varying spacing within a productive area. The comparisons have been made by computing spacing and recoveries by quarter sections; grouping them by 4-acre spacing increments as follows: zero to 4 acres, 4 to 8 acres, 8 to 12 acres, and more than 12 acres, and averaging the spacing and recovery per acre foot for those groups.

Since some of the conditions affecting this production are exceptional, they merit brief discussion.

The production occurs in a truncated sand body on the flank of the anticline.

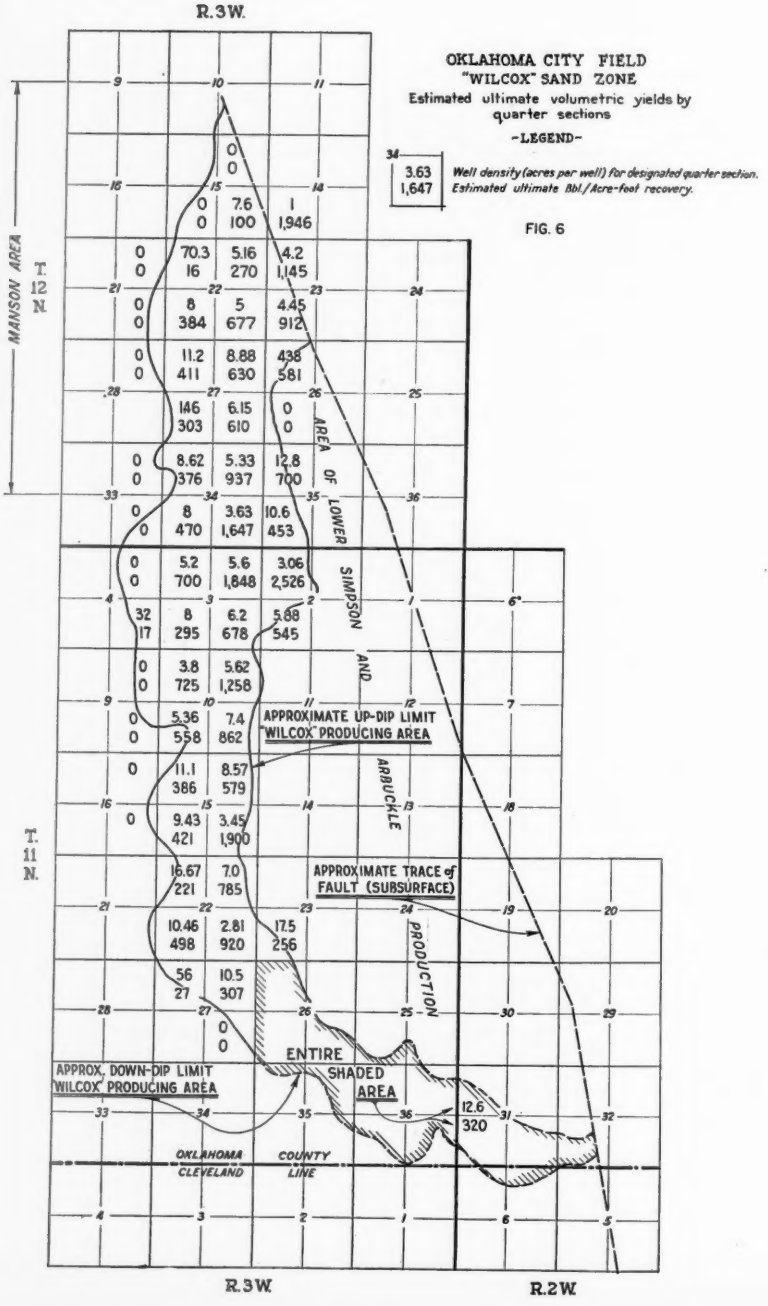

R.3W.
OKLAHOMA CITY FIELD
"WILCOX" SAND ZONE
Estimated ultimate volumetric yields by quarter sections
-LEGEND-
3.63 Well density (acres per well) for designated quarter section.
1,647 Estimated ultimate Bbl./Acre-foot recovery.
MANSON AREA
T. 12 N.
AREA OF LOWER SIMPSON AND ARBUCKLE PRODUCTION
APPROXIMATE UP-DIP LIMIT "WILCOX" PRODUCING AREA
APPROXIMATE TRACE of FAULT (SUBSURFACE)
ENTIRE SHADED AREA
APPROX. DOWN-DIP LIMIT "WILCOX" PRODUCING AREA
T. 11 N.
OKLAHOMA COUNTY LINE
CLEVELAND
R.3W
R.2W

FIG. 6

In cross section normal to the strike of the beds, the pay sand represents a prism (Fig. 5), bounded by the upper and lower surfaces of the sand, the original water level, and the unconformity at the base of the Pennsylvanian. Total thickness of the sand is about 225 feet.

A, *B*, and *C* indicate wells penetrating the "pay," respectively, near the updip edge, in the middle of the productive zone, and near the downdip edge. It is evident that wells near the updip edge produce from the lower part of the sand, those near the middle from almost the entire sand body, and those near the downdip edge produce from the upper part of the sand only.

Obviously the wells in the updip part of the productive zone are in the best position to benefit from any updip drainage that may occur.

The areal extent of the productive area is shown in Figure 6.

It happens that for the major part of its length, the productive area extends north and south and is practically spanned by two adjacent rows of quarter sections. If recoveries per acre foot of sand and well spacings are computed by quarter sections and posted on the map, it immediately becomes apparent that of adjoining quarter sections in these two rows, that on the updip side invariably has the higher recovery regardless of well spacing.

At first glance, this seems to be evidence of updip drainage on a large scale. However, there are certain other facts that cast doubt on that conclusion. There has been no active water drive in this sand. Many wells near the updip edge have been depleted and abandoned. The pressure has been reduced nearly to atmospheric, and drainage into the presently producing wells appears to be by simple gravity flow. Furthermore, the phenomenon of higher yield from the updip quarter sections persists up through the Mansion area where the pressure had been reduced to about 700 pounds during the years before the development of that area began.

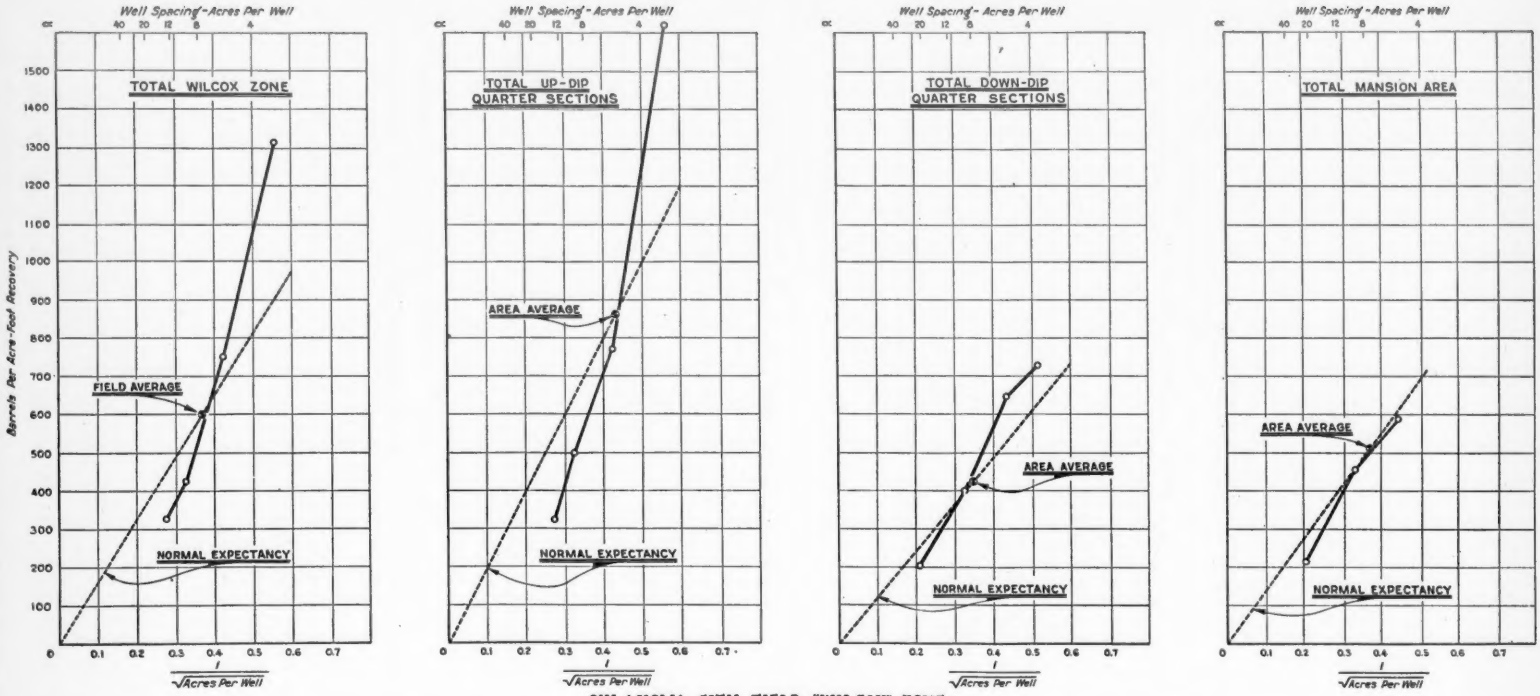
All this suggests that the bottom half of the sand is inherently a better pay zone than the top half.

Plotting the data for the 4-acre increments for the entire sand body and the updip and downdip quarter sections, respectively, on the Well Spacing-Recovery chart, gives the first three graphs shown in Figure 7.

The three curves have one characteristic in common: they have a steeper slope than that indicated by the over-all averages, and there is a slight tendency for the slope to increase as well spacing diminishes. In other words, the increase in recovery with closer spacing is greater than would normally be expected.

The range of recoveries even for these 4-acre increments is extremely large, ranging from 325 barrels per acre foot for a spacing of 13.25 acres per well, to 1,315 barrels per acre foot for a spacing of 3.25 acres per well for the entire "Wilcox" area. Individual quarter sections, of course, show an even wider range.

The data for the later developed "Mansion area," plotted on the Well Spacing-Recovery chart (Fig. 7), indicate an average recovery approximately 14 per cent lower than that of the entire sand body, but 22 per cent higher than the


Well Spacing - Acres Per Well
∞ 40 20 12 8 4
TOTAL WILCOX ZONE
FIELD AVERAGE
NORMAL EXPECTANCY
Barrels Per Acre-Foot Recovery
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
1/√Acres Per Well
TOTAL UP-DIP QUARTER SECTIONS
AREA AVERAGE
NORMAL EXPECTANCY
TOTAL DOWN-DIP QUARTER SECTIONS
AREA AVERAGE
NORMAL EXPECTANCY
TOTAL MANSION AREA
AREA AVERAGE
NORMAL EXPECTANCY

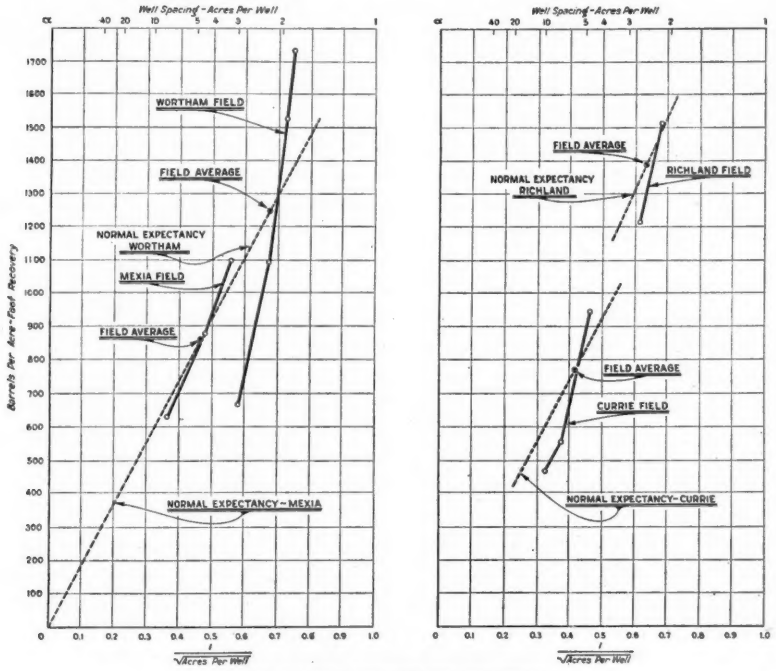
OKLAHOMA CITY FIELD - "WILCOX" ZONE

Estimated ultimate recoveries calculated by quarter sections and grouped in spacing intervals of four acres per well.

FIG. 7

average of the downdip quarter sections. The recovery curve approaches the normal-expectancy line for the area more closely than any of the other three curves; but even it shows a slightly steeper slope than the normal-expectancy line.

The phenomenon of steeper than normal gradients on the well spacing-recovery curves for intra-field groups also is evident in Figure 8, in which the production from the Texas fault-line fields has been broken down by spacing increments



INTRAFIELD SPACING - RECOVERY RELATIONSHIPS
TEXAS FAULT LINE FIELDS
Showing effects of spacing on recovery within individual fields

FIG. 8

within the fields. With the exception of Wortham, the deviations from the normal-expectancy line are slight; but all the deviations are toward a steeper gradient rather than a flatter one.

This indicates that for the intra-field spacing groups, the more closely spaced wells are benefited; and the more widely spaced ones penalized to a greater degree than would be expected from the inter-field comparisons. In other words, that with varied spacing within a field, the closely spaced wells gain an additional ad-

vantage at the expense of the widely spaced ones. The steepening of the gradients of the intra-field curves provides an index of the extent of that effect.

Comparison of the Oklahoma City curves with those of the fault-line fields indicates that proration as practiced at Oklahoma City tended to aggravate that effect rather than to mitigate it.

Much additional evidence offering support for the proposition that closer spacing does mean increased recovery might be added. But enough has been presented to establish not only the fact of increased recovery with closer spacing, but that of a definite mathematical relationship between the two. The evidence shows that within the range of ordinary experience this relationship holds, not only for shallow fields and wide-open producing conditions, but for comparatively deep production developed with relatively wide spacing and operated under proration with its restrained rates of production.

The mere fact that this simple relationship obviously can not continue to hold throughout the entire range to infinity in the direction of closer spacing, does not invalidate it for use within practical limits. In this respect, it is analogous to the laws of gases which are useful tools within the critical temperatures and pressures which limit their application.

That mathematical relationship is presumably an index of the unavoidable losses inherent in any system of oil-field development in which recovery of the oil depends on forcing it to a series of isolated points within the reservoir; that is, the drill holes penetrating the sand, in somewhat the same way as entropy is a measure of the unescapable loss in any heat-power engine. It seems obvious that some loss is inevitable in the oil-well method of exploitation as compared with actual mining of the sand and washing it free of oil, or as compared with pumping oil through a pipe line.

Probably a substantial part of the increased loss accompanying wider spacing may be attributed to the fortuitous location of the drill holes in the reservoir with respect to the areas of exceptionally high porosity and permeability in sandstones or the naturally developed drainage channels in limestones or dolomites. All reservoir rocks vary laterally in some degree. As a consequence, individual wells vary greatly in their productive capacities. One well may yield as much as half a dozen of its neighbors. At the other extreme are the dry holes which are completed in the hearts of fields due solely to local impermeable areas in the producing formation.

The odds against tapping all the local "sweet spots" naturally increase as well spacing widens, and no doubt that fact is reflected in the lower average recoveries per acre foot indicated for more widely spaced wells.

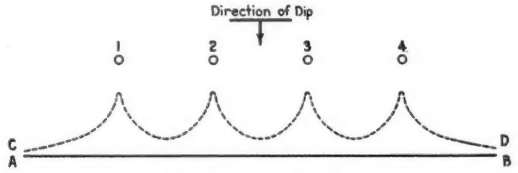
It is not necessary to undertake an exhaustive analysis of the problem of radial drainage to visualize other reasons for such losses. Pressure gradients along any radius through a producing well are steep in the immediate vicinity of the hole and flatten in a short distance from it. The pressure-divides between wells may be visualized as almost imperceptible reversals rather than sharp ridges.

In exclusively solution-gas-drive fields, it is inconceivable that the oil along

these pressure-divides could ever be moved to the wells by the energy originally available in the reservoir.

In water-drive fields where water from outside the original oil accumulation is available for replacement of fluid removed and provides a source of replenishment of energy, we should expect a greater recovery than in the gas-drive field. However, pressure-divides between wells will still exist, and movement of the water toward the wells will tend to be along the steepest pressure gradient and accordingly the shortest line.

Figure 9 illustrates a situation in which wells 1, 2, 3, and 4 are equally spaced and are equidistant from the original oil-water contact line *AB* at the top of the producing sand. Since oil in most natural reservoirs does not have the same freedom of movement as in an open vessel, but must be moved through openings of capillary size at an appreciable expenditure of energy, it seems evident that after a lapse of time the oil-water contact would assume the position indicated by the broken line *CD*.



Plan diagram showing probable change of oil-water contact line at the top of a producing sand in a water drive field as the oil is produced through wells 1, 2, 3 & 4.

FIG. 9

Such lobes in the advancing water front would become further accentuated as production continues, with the result that some oil along the pressure-divides would presumably eventually be by-passed entirely even in an ideal sand with uniform porosity and permeability throughout. In actual practice, of course, both lateral and vertical variations in the reservoir rock generally prevent the development of anything approaching a uniform water front moving through the sand, which, of course, aggravates the matter of by-passing.

It also seems evident that the lobes pictured in Figure 9 would be the more strongly developed, the greater the distance between wells; although it would require infinitely close spacing; that is, trench rather than well exploitation, and consequent linear rather than radial drainage to eliminate them entirely.

Granted the hypothesis that the indicated mathematical relation between well spacing and recoveries is an index of the inherent inefficiency of the well system of oil-field development, there is no justification for the assumption that that relation can be destroyed by the adoption of different production practices.

Certainly restraint of the rate of production as practiced at Lucien did not affect it materially.

Nor is there any reason to think that repressuring by the recycling of casing-head gas, the introduction of gas from extraneous sources, or the use of an artificial water drive can wholly eliminate the effect of well spacing. They can effect increases in recovery it is true; but they all involve the creation of steeper pressure gradients along straight lines from the input wells to the nearest producers than exist along other radii from those producers, with a consequent tendency to by-pass oil along the intervening pressure-divides.

Within certain practical limits there is no reason to assume that the adoption of a more efficient production method would not effect an increase in recovery, regardless of the existing well spacing.

The total volume of oil originally present in the reservoir constitutes the final limit which all efforts toward increased recovery can only hope to approach. It is highly desirable that the general order of magnitude of the figures as they apply to the unit of reservoir volume be kept in mind. An acre foot of sand occupies a space approximately equivalent to 7,750 barrels of 42 gallons each.

An acre foot of sand with a porosity of 25 per cent therefore contains void space amounting to 1,937 barrels. If 15 per cent of that space is occupied by connate water, that available for oil is reduced to 1,560 barrels. And if 15 per cent of the volume of the oil represents dissolved gas, the space occupied by "tank-battery" oil shrinks to 1,325 barrels. Those figures convey a fair idea of the outside limitations on the productive possibilities of a sand with 25 per cent porosity.

As those limits are approached, it is obvious that further appreciable increases can not be expected from either closer spacing or refinements in production practice.

A close approach to those limits as a result of close spacing is indicated by the Wortham field recovery of 1,245 barrels per acre foot with a spacing of 2.2 acres per well under the wide-open-flow conditions which have frequently been branded as inefficient and wasteful. It should be noted that the increased recovery attributable to closer spacing is a very substantial figure. Thus, Wortham's 1,245 barrels represent an increase of 475 barrels or 62 per cent over the 770-barrel recovery at Currie. The total indicated gain at Wortham amounts to 8,950,000 barrels.

It should be obvious that any improvement in production practice which can demonstrate a recovery equal to that obtained at Wortham, from a sand of equal porosity with a decidedly wider spacing, will eliminate any need for consideration of any closer spacing than that then used. Certainly unless they do result in recovery comparable with that obtained at Wortham, porosity and other factors considered, no production practices applied to widely spaced wells can eliminate all need for considering the possibilities of obtaining additional oil by means of closer spacing.

All the foregoing discussion has considered only the effects of spacing within the field. If all fields were limitless in extent, no other factor would need consideration. But oil fields are limited in area; and authorities agree that the average size of fields discovered in the United States during recent years has shown a

persistent decline. This decline in field size, coupled with arbitrarily imposed wide-spacing patterns which now generally prohibit drilling more than one well to 40 acres, has created additional problems which can not be ignored in any study of the economic effects of well spacing.

One of these is the problem of obtaining locations actually capable of draining structurally controlled accumulations in fields of small areal extent under arbitrary wide-spacing patterns. This includes narrow accumulations against faults, where adequate development becomes a veritable nightmare under existing spacing regulations, and all sharply folded anticlines and domes of small extent.

The nature of the problem may be indicated by carrying it to an extreme for illustrative purposes. If the regulations specified that only one well could be drilled in each section of land, and that it must be located at the center of the section, it is evident that many small fields could not be exploited at all because of the impossibility of finding any location on the regular pattern which would fall within their limits.

The same difficulty in principle arises when an operator attempts to select locations on a rigid, uniform 40-acre spacing pattern to exploit a given pay zone in a narrow fault-trapped field.

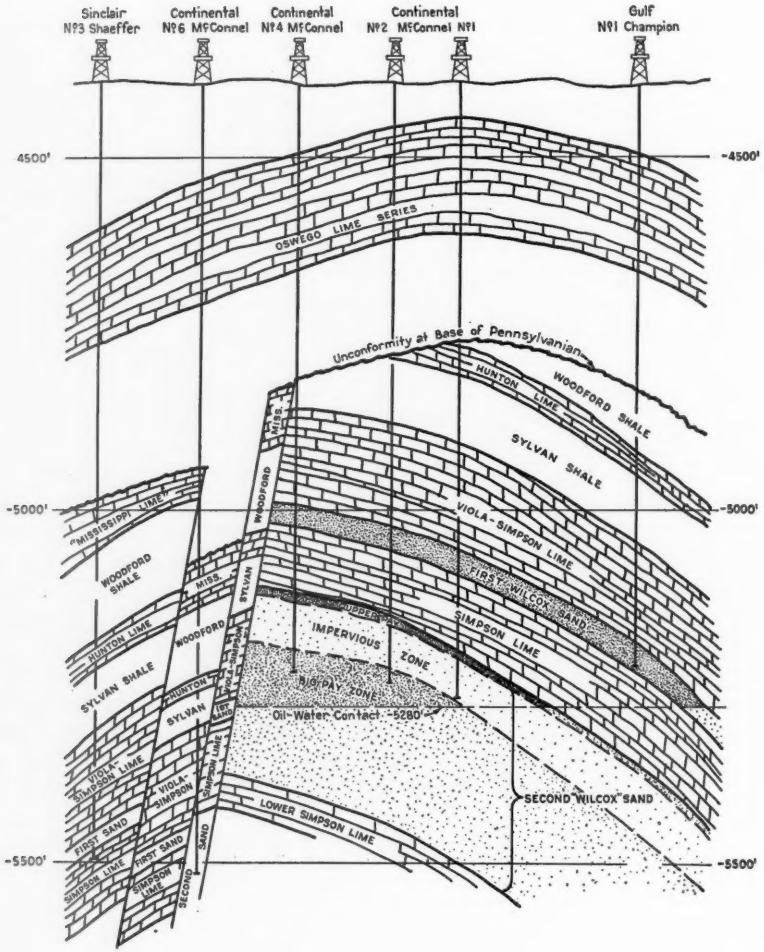
The "Wilcox" sand production in the Crescent field, Oklahoma, furnishes a perfect illustration of the problem as it applies to a narrow sharply folded and faulted anticline. It is a particularly pertinent example because the field development was initiated on a 40-acre spacing, but was subsequently switched to a 10-acre pattern as a result of vigorous protests by some of the operators affected.

It happens that the axis of the structure in the Ordovician rocks runs practically north and south. Consequently, the east-west cross section (Fig. 10) indicates the relative positions of the north-south rows of 10-acre and 40-acre locations, respectively, that are closest to that axis. The Second "Wilcox" sand in this field included a tightly cemented practically impermeable zone below its upper pay zone. Beneath that tightly cemented zone was a lower "pay" of exceptional caliber in which initial productions ranging up to 64,000 barrels per day were obtained.

Only the two rows of 10-acre locations along the crest of the structure produced from the prolific lower pay zone. Those producers are indicated and the initial productions of both the First and Second "Wilcox" sand wells are shown in Figure 11.

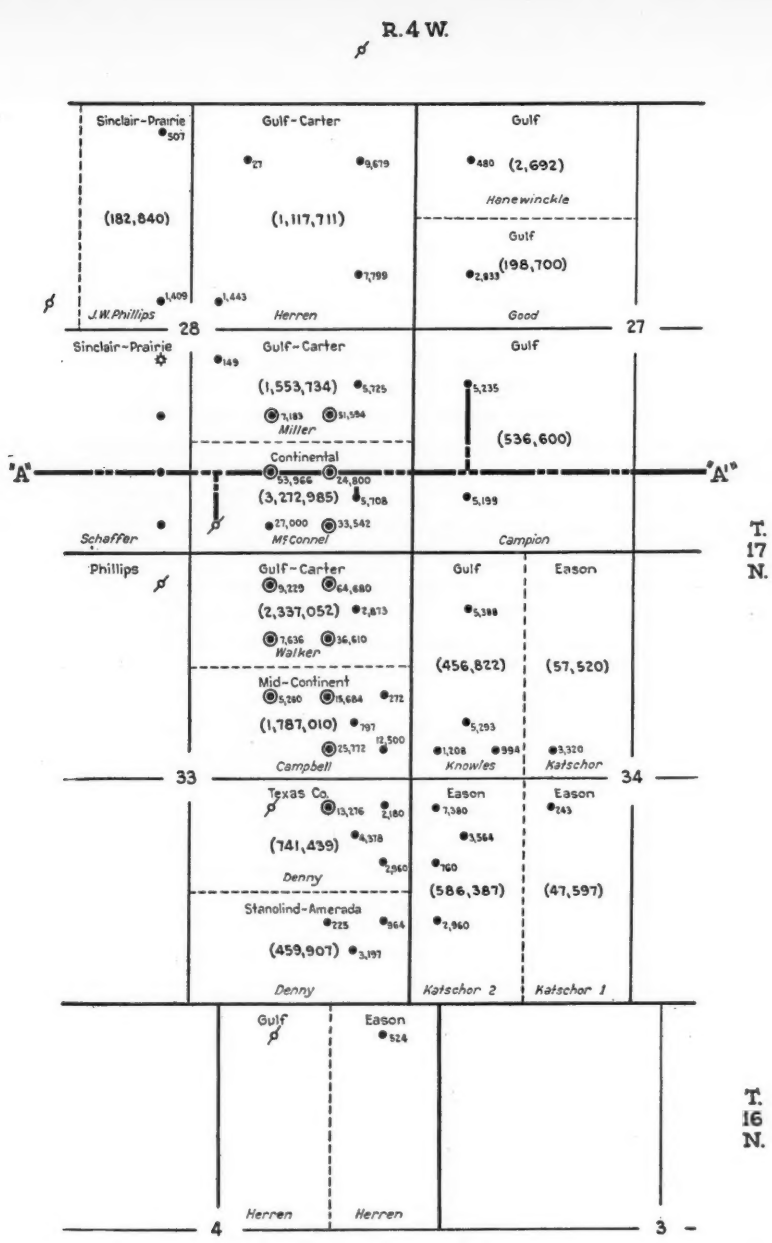
Production from the leases shown has amounted to 13,338,996 barrels. Though segregated production figures are not available, it seems probable that more than half of the total was obtained from the extremely productive lower pay zone which would never have been tapped if the original 40-acre spacing had been followed throughout the development.

The particular difficulty of selecting structurally satisfactory locations on a rigid spacing pattern could be mitigated materially without increasing average well density by a simple ruling that equal density of development does substan-



CRESCENT POOL - OKLAHOMA
CROSS SECTION "A-A'"
Showing limited extent of "Big Pay Zone" in the second "Wilcox" sand.

FIG. 10



CRESCENT • FIELD – OKLAHOMA

"WILCOX" SAND DEVELOPMENT ONLY

Showing wells which penetrated "Big Pay Zone" in second "Wilcox" horizon; initial production by wells; and cumulative production.

–LEGEND–

- • – *Wells completed in first "Wilcox" or top of second "Wilcox."*
- ◉ – *Wells completed in "Big Pay Zone" of second "Wilcox."*
- 2,873 – *Initial potential – 24 hour.*
- (57,520) – *Lease cumulative production to July, 1943.*

FIG. 11

tial justice as between adjoining operators and royalty owners, and, consequently, that having established the density by fixing the area to be included in a drilling unit, all further restrictions, as to where within that unit the well may be drilled, will be eliminated. In fact, such a ruling seems essential as a matter of justice to both operators and royalty owners.

Another problem created by wide spacing lies in the increased ratio of dry holes to producers drilled in developing a field. As field area diminishes, that ratio tends to increase, well spacing being constant. The extreme case is that of the one-well pool with dry holes offsetting it in each of the four cardinal directions. That situation will naturally be reached sooner with a wide-spacing pattern than with a close one as field size declines. The same tendency exists in fields of greater extent. Thus, with decreasing field size and increasingly wider well spacing, a large increase is inevitable in the percentage of total footage drilled which goes into the unproductive holes required to determine the limits of a field.

If one well will not effect the same recovery as a number of wells will from a reservoir, regardless of size, then there is a definite loss involved in this increasing percentage of dry-hole footage which serves to offset or cancel out a part of the apparent saving in development cost credited to wider spacing.

Discussions of the effect of well spacing on profits in recent years have for the most part assumed that recovery would be independent of spacing and, consequently, that the reduction in development cost effected by widening the spacing is all net saving. If this were literally true, there would be no justification for drilling more than one well in the smaller fields.

There has also been a tendency to focus attention upon development costs (in terms of cost per producing well only) and profits per dollar invested (with the same restriction as to investment items). Such a presentation of the subject gives a very seriously distorted picture. It is heavily "loaded" to favor wide spacing since "development cost," figured on a flat price per well, increases in direct ratio to the number of wells drilled; whereas, the recovery of oil increases only in proportion to the square root of well density.

There is little excuse for such distortion of the facts, since the actual possibilities for reductions in costs through wider spacing should be sufficient argument for the adoption of as wide a spacing as is practicable and economically sound.

It is the further purpose of this discussion to indicate the factors which must be taken into consideration to arrive at any fair appraisal of what is practicable and economically sound. Those factors are: (1) the recovery per acre obtainable; (2) the price of the oil; (3) the cost of finding and acquiring each productive acre (including the cost of condemned acreage and exploratory dry holes); (4) the cost of development per productive acre (including probable cost of dry holes drilled to define field); (5) the probable cost of producing the oil; and (6) the practicability (as a physical possibility) of adequately exploiting a particular accumulation with a given spacing pattern.

Total recovery per acre for a known thickness of pay may be estimated with

the aid of the Well Spacing-Recovery chart, by use of a point established by known recovery for one spacing from a closely comparable reservoir operated under similar conditions, and the zero point of the chart to determine a line along which unit recoveries for other spacings may be read. Multiplying those figures by the pay thickness gives the total recovery figures.

The price of oil used would normally be the prevailing field price. However, it may at times be desirable to extend the investigation to include the effects of a range of prices. And under conditions of extreme depression or boom, it is advisable to use a price representing the reasonable expectancy over a long period of years.

The cost of finding and acquiring each productive acre has generally been ignored in studies of the economics of well spacing. But to do so is to assume that an unlimited supply of oil fields is available upon which an operator may move at will and begin exploitation with no prior expense.

Nothing could be farther from the truth. The proved but undeveloped leases available to any operator for exploitation are definitely limited in number. On the average they represent a large investment in the form of scouting, land, geological, and geophysical expense, lease bonuses and rentals, and unsuccessful wildcat tests. Certainly, if an individual company is to remain in business and the industry as a whole is to remain solvent, all these costs must be returned out of the operating profits from the productive leases.

Furthermore, these items in total represent a flat charge per acre *which accordingly becomes an increasing charge per well as spacing is widened.* To illustrate with the simplest possible case, if an individual with no other investment in the oil industry were to buy a proved but undeveloped lease on 160 acreas at a cost of $2,000 per acre, that bonus cost would represent his entire "finding and acquisition cost." The entire amount obviously must be returned out of net revenue from operations on the lease before any profit can be realized.

The amounts of the bonus cost chargeable to individual wells under various well spacings is indicated in the following tabulation.

Total Finding and Acquisition Cost per Acre	*Well Spacing Acres per Well*	*Finding and Acquisition Cost Chargeable to Each Well*
$2,000	10	$20,000
$2,000	20	$40,000
$2,000	40	$80,000

Each operator can determine his unit finding and acquisition cost by totaling all land, scouting, and exploration costs, including exploratory dry holes, over a period of years and dividing that total by the number of acres brought into production during the same period. For the industry as a whole, that cost is probably in excess of $1,000 per acre.

The cost of developing a lease to a certain formation with a given well density can be accurately estimated. The only comment concerning it that seems necessary is that for a fair comparison for different well densities the items of cost

should be broken down into two classes; the cost of the wells themselves, and the cost of the other facilities necessary for the operations. Only the cost of the wells increases in direct proportion to the number drilled. Other development costs, such as tankage, lease houses, warehouses, and water systems, are largely independent of the well spacing adopted.

In figuring comparative development costs per acre for various well spacings, the cost of dry holes required to define the limits of production should properly be included.

This may be treated as a constant number of wells for a field, although in practice the number increases with wider spacing.

Direct lease expense, or lifting cost, in contrast to well costs, does not increase in proportion to the number of wells drilled. One-well leases are notoriously high-cost operations. The organization required to operate a field developed on 10-acre spacing is only slightly larger than that required if the spacing is 20 acres per well. Unit lifting costs consequently decline as well density increases; or the additional oil recovered by closer spacing can be lifted at a fraction of the cost per barrel chargeable against that part of the oil recoverable through the wider-spacing pattern.

Determining the practicability, from the standpoint of physical possibilities, of a certain spacing pattern for the exploitation of a field, simply involves an examination of those possibilities in the light of the physical conditions controlling the accumulation. The difficulties involved in attempting to develop small sharply folded structures or narrow multiple-sand accumulations against inclined fault planes on wide-spacing patterns have previously been discussed.

TABLE V

COMPARISON OF EFFECTS OF VARIOUS WELL SPACINGS

Item	*Well-Spacing Pattern—Acres per Well*			
	40	*20*	*10*	*5*
Productive acres	1,600	1,600	1,600	1,600
Sand thickness (average feet)	35	35	35	35
Recoveries (barrels)				
Per acre foot	175	250	350	500
Per acre	6,125	8,750	12,250	17,500
Total	9,800,000	14,000,000	19,600,000	28,000,000
Net oil to $\frac{7}{8}$ working interest	8,575,000	12,250,000	17,150,000	24,500,000
Price (net after prod. tax)	1.20	1.20	1.20	1.20
Gross working interest revenue	$10,290,000	$14,700,000	$20,580,000	$29,400,000
Costs: finding and acquisition at $1,000 per acre	1,600,000	1,600,000	1,600,000	1,600,000
Development (No. wells)	40	80	160	320
Wells at $30,000 each	$ 1,200,000	$ 2,400,000	$ 4,800,000	$ 9,600,000
Dry holes 6 at $17,500	105,000	105,000	105,000	105,000
Other facilities at $300 per acre	480,000	480,000	480,000	480,000
Total development	$ 1,785,000	$ 2,985,000	$ 5,385,000	$10,185,000
Lifting costs per barrel	0.25	0.188	0.147	0.118
Total	2,450,000	2,632,000	2,881,000	3,304,000
Total costs	5,835,000	7,217,000	9,866,000	15,089,000
Net profit	4,455,000	7,483,000	10,714,000	14,311,000
Cost per net barrel	0.68	0.589	0.575	0.615
Profit per dollar of costs	0.763	1.03	1.08	0.948

Table V presents an analysis of the effects of various well spacings in terms of over-all costs and profits and in costs per net barrel of oil recovered and profits per dollar of total costs, in a hypothetical case based on assumptions of field size, sand thickness and productivity, well costs, *et cetera*, which are well within the range of ordinary experience.

This analysis takes all of the foregoing factors into consideration. (It is assumed that the dimensions of the productive area are such that it can be exploited by any of the spacings indicated.) Consequently, it may be regarded as a fair comparison of the effects of different spacings.

The resulting figures may be rather startling to those who have become accustomed to thinking that wider spacing invariably means a great saving, with consequently reduced unit costs and increased profits. For the conditions stated it is evident that, from the strictly cold-blooded standpoint of costs per net barrel of oil recovered and profits per dollar expended, the 10-acre spacing has the advantage over either the 20- or 40-acre spacings; and it is only when the density of one well to 5 acres is reached that the additional oil recovered involves the penalties of higher unit costs and decreased profits per dollar of costs.

It should be emphasized that the barrel of oil in lease storage awaiting acceptance by the pipe line is the oil producer's finished product. Every item of cost incident to putting it there must be considered to obtain a fair comparison of the economic effect of different well spacings. The omission or misapplication of any of those figures can result only in distorted results.

Its *pro rata* share of the total of those costs represents the operator's investment in that barrel of oil; and it is the profit per dollar of that investment which is significant rather than the apparent profit from lease operations only expressed in terms of an "investment" figure covering lease investment only and computed on a flat well-cost basis.

CONCLUSIONS

The evidence presented makes the following conclusions unescapable.

1. Well spacing does affect the recovery of oil from a reservoir; increased well density results in increased recovery; and, within practical limits there is a definite mathematical relationship between the well spacing and the recovery.

2. Arbitrary wide-spacing regulations impose definite handicaps on the adequate exploitation of small accumulations on sharp folds or against faults, and increase the ratio of dry holes to producers.

3. Even from the standpoint of cost per barrel of crude recovered and of profit per dollar expended, it is not invariably true that the wider of two spacings is the more economical. For a given set of conditions there is a certain spacing which is most economical, and either a closer or a wider spacing involves higher *unit* costs and lower *unit* profits.

Certain other conclusions may legitimately be drawn from these basic ones.

While nothing herein is to be construed as an argument against the adoption

of improved production practices in the attempt to obtain greater recoveries at lower costs, it appears that a simple and highly effective method is being neglected when the possibilities of close spacing are ignored.

Since more wells mean increased recovery, there is a strong incentive to work toward lower development costs by utilizing every expedient to reduce the cost of the individual well rather than by widening the spacing.

Where wide spacing is temporarily adopted either because of material shortages or lack of information regarding the reservoir, it is highly desirable that a pattern be selected which will permit increasing the density by drilling intervening wells later.

With the existing urgency for an augmented crude supply, it seems logical to resort to the drilling of additional wells in fields now having wide spacing which are favorable to closer spacing, especially since such drilling would add potential production, and reserves, with a minimum of equipment as contrasted with the material requirements for exploiting new fields.

And, finally, since optimum well density varies with crude prices, it appears to be in the public interest for crude-oil prices to be increased to levels which would encourage relatively close well spacing so long as the present downward trend of discoveries in relation to production continues.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 2 (FEBRUARY, 1944), PP. 257-277, 1 FIG.

DEVELOPMENTS IN NORTH LOUISIANA AND SOUTH ARKANSAS IN 1942[1]

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ABSTRACT

During the year 1942, 26,474,610 barrels of oil and distillate were produced in South Arkansas and 32,491,304 barrels in North Louisiana. In December, 1942, there were 3,041 oil and distillate producing wells in South Arkansas and 4,494 wells in North Louisiana.

Two hundred fourteen wells were drilled in South Arkansas during 1942 with the total footage of 1,094,223 feet. In North Louisiana, 527 wells were drilled with the total footage of 2,257,530 feet. The average depth of wells drilled in South Arkansas during 1942 was 5,113 feet compared with 4,121 feet during the year of 1941; for North Louisiana, the average depth for 1942 was 4,280 compared with 2,952 feet for the year of 1941. Of the total of 741 wells drilled in South Arkansas and North Louisiana, 400 were oil wells, 81 were gas and gas-distillate wells, 125 were dry holes in fields, and 135 were wildcat dry holes.

The major discovery in South Arkansas during 1942 was the Midway field in Lafayette County, producing oil from the Smackover limestone. Smackover limestone gas-distillate production was discovered in the Columbia field in Columbia County, and in the Texarkana field in Miller County. The New London field in Union County, a 1942 discovery, produces oil from several sands in the lower Cotton Valley section. Cotton Valley sand production was also discovered in three Smackover limestone producing fields: oil in the McKamie field, Lafayette County, and gas-distillate in the Dorcheat and Macedonia fields in Columbia County.

In North Louisiana during 1942, three Wilcox sand oil fields were discovered in La Salle Parish, and the Lake St. John Wilcox sand field in Concordia Parish. The latter field also produced gas-distillate in the basal Tuscaloosa (Upper Cretaceous) sand in the deep discovery well. A Sparta sand gas well was completed in the Lake St. John field, a Sparta sand oil well in Catahoula Parish, and two Cockfield sand oil wells in the Nebo field.

A Paluxy sand gas-distillate producer was discovered in Winn Parish. A small oil well was completed in a Cotton Valley sand northeast of the Monroe gas field in Morehouse Parish. A new Pettit limestone field was discovered near the Louisiana-Arkansas state line in the North Cartersville area.

INTRODUCTION

Total production figures for South Arkansas for the year 1942 show a slight increase over 1941 production figures. The newly discovered Smackover limestone production of the Midway field more than offsets the normal production decline of the older fields. Total production figures for North Louisiana for 1942 show an increase of nearly 6 million barrels over 1941, due to routine developments of the Wilcox production in the Nebo and Little Creek fields and the development of Pettit limestone production in the Haynesville field.

TABLE I

BARRELS OF OIL AND DISTILLATE PRODUCED, SOUTH ARKANSAS AND NORTH LOUISIANA

	1941	*1942*	*Accumulated to End of 1942*
South Arkansas	26,183,478	26,474,610	548,692,882
North Louisiana	26,770,512	32,491,304	571,149,492
Total	52,953,990	58,965,914	1,119,842,374

[1] Presented by title before the Association at Fort Worth, April 7-9, 1943. Manuscript received, December 4, 1943. Published with the permission of the Gulf Refining Company.

[2] Geologist, Gulf Refining Company.

TABLE II

STRATIGRAPHIC DISTRIBUTION OF 1942 OIL AND DISTILLATE PRODUCTION (BARRELS)*

	South Arkansas	*North Louisiana*	*Totals*
Tertiary Eocene	—	10,544,600	10,544,600
Upper Cretaceous	6,180,700	3,522,300	9,703,000
Lower Cretaceous	2,609,300	13,511,000	16,120,300
Jurassic	17,746,700	4,987,600	22,734,300
Total	26,536,700	32,565,500	59,102,200

* Estimated in part: figures of Table II include some distillate production not included in Table I.

PERCENTAGE DISTRIBUTION

	South Arkansas	*North Louisiana*	*Totals*
Tertiary Eocene	—	32.4	17.9
Upper Cretaceous	23.2	10.8	16.4
Lower Cretaceous	9.8	41.5	27.3
Jurassic	67.0	15.3	38.4

TABLE III

STRATIGRAPHIC DISTRIBUTION OF PRODUCING WELLS COMPLETED DURING 1942

	South Arkansas			*North Louisiana*		
	Oil	*Gas-Dist.*	*Gas*	*Oil*	*Gas-Dist.*	*Gas*
Tertiary Eocene						
Claiborne	—	—	—	3	—	1
Wilcox	—	—	—	104	—	3
Sub-Total	—	—	—	107	—	4
Upper Cretaceous						
Monroe gas rock	—	—	—	—	—	28
Nacatoch	13	—	—	13	—	1
Chalk rock	—	—	—	14	—	—
Tokio	5	—	—	3	—	—
Sub-Total	18	—	—	30	—	29
Lower Cretaceous						
Paluxy	7	—	—	23	1	—
Lower Glen Rose and "Travis Peak"	17	—	—	132	—	4
"Travis Peak"	—	—	—	2	1	4
Sub-Total	24	—	—	157	2	8
Jurassic						
Cotton Valley	21	5	—	1	3	—
Smackover limestone	42	17	—	—	1	—
Dual completions	—	12	—	—	—	—
Sub-Total	63	34	—	1	4	—
Total	105	34		295	6	41

TABLE IV

NUMBER OF WELLS AND TOTAL FEET DRILLED DURING 1942

	South Arkansas		*North Louisiana*		*Total*	
	No.	*Feet*	*No.*	*Feet*	*No.*	*Feet*
Oil wells	105	475,987	295	1,278,659	400	1,754,646
Gas and gas-dist. wells	34	256,127	47	184,890	81	441,017
Dry holes in fields	34	173,818	91	332,736	125	506,554
Dry holes—wildcats	41	188,291	94	461,245	135	649,536
Total	214	1,094,223	527	2,257,530	741	3,351,753

SUMMARIZED DISCUSSION OF DISCOVERIES IN SOUTH ARKANSAS IN 1942

COLUMBIA COUNTY

COLUMBIA FIELD (SMACKOVER LIMESTONE GAS-DISTILLATE DISCOVERY)

SEC. 23, T. 17 S., R. 21 W.

The discovery well of the Columbia field, Roy Lee Trustee's Pickler No. 1, Sec. 23, T. 17 S., R. 21 W., was completed, December 31, 1942, as a gas-distillate producer from the Smackover limestone. Casing was gun-perforated between depths of 8,051 and 8,055 feet with 32 shots; the well was completed, flowing 100 barrels of 68° gravity distillate in 24 hours through a 14/64-inch tubing choke, 0.001% sediment and water; tubing pressure, 2,200 pounds; casing pressure, 2,500 pounds; gas-oil ratio, 14,000/1.

The Columbia field is approximately one mile south of the city limits of Magnolia and 3 miles due west of the most westerly oil well in the Magnolia field. The location of the

TABLE V

ESTIMATED TONS OF CASING USED DURING 1942*

	South Arkansas			*North Louisiana*		
	Prod. Wells	*Dry Holes*	*Total*	*Prod. Wells*	*Dry Holes*	*Total*
Oil fields	6,994	496	7,490	17,689	1,636	19,325
Gas and gas-dist. fields	3,514	213	3,727	2,715	136	2,851
Wildcats	—	668	668	—	1,690	1,690
Total tons	10,508	1,377	11,885	20,404	3,462	23,866

TOTALS—SOUTH ARKANSAS AND NORTH LOUISIANA

	Prod. Wells	*Dry Holes*	*Total*
Oil fields	24,683	2,132	26,815
Gas and gas-dist. fields	6,229	349	6,578
Wildcats	—	2,358	2,358
Total tons	30,912	4,839	35,751

* Salvaged casing not estimated.

discovery well was made on a seismograph prospect which reportedly had a small amount of closure on top of the Smackover limestone. The Roy Lee Trustee well is approximately 485 feet lower structurally on top of the Smackover limestone than the most westerly producing well in the Magnolia field. Smackover limestone cores of the Reynolds "oölite" member showed porosity ranging from 14% to 22%, average 18.7%; permeability ranging from 4 to 649 millidarcys, average 179; residual saturation 5.8% to 19.6%, average 12.7%. The subsea depth of the oil-water contact in the Magnolia field occurs between −7,320 and −7,330 feet. The gas-distillate-water contact occurs at subsea depth of −7,890 feet in the Roy Lee Trustee well. From these data, it appears that the Roy Lee well is on a small closed structure on the west projection of the main east-west axis of the Magnolia structure. The following formational contacts were logged in the discovery well: top Saratoga chalk 2,165 feet; base Annona chalk 2,487 feet; top first Tokio sand 2,683 feet; base Tokio-top Eagle Ford 3,003 feet; Lewisville volcanics 3,140–3,165 feet; Upper Cretaceous-Lower Cretaceous contact 3,165 feet (Lewisville volcanics resting on Upper Glen Rose); Ferry Lake (massive) anhydrite 3,504–3,662 feet; top James limestone 4,207 feet; top "Travis Peak" 4,625 feet; top Cotton Valley 5,855 feet; top Buckner 7,920 feet; top Smackover limestone 8,004 feet; total depth 8,116 feet. The areal extent of the Columbia field can not be forecast at this time.

TABLE VI

Drilling Activities in South Arkansas Oil Fields During 1942

County	Field	Oil Wells: No.	Oil Wells: Feet Drilled		Oil Wells: Total Initial Bbls.	Oil Wells: Total Initial MM	Oil Wells: Average Initial Bbls.	Oil Wells: Average Initial MM	Dry Holes: No.	Dry Holes: Feet Drilled
Columbia	Atlanta	2	16,410	(2) Smackover limestone	708	3.4	354	1.7	—	—
Columbia	Dorcheat (Gas-dist. field)	2*	8,960	(1) Cotton Valley (1) Smackover limestone	147 240	1.2 1.2	147 240	1.2 1.2	— —	— —
		* 1 Smackover limestone; 1 Cotton Valley rework								
Columbia	Haynesville (North flank)	1	5,540	(1) Pettit	164	—	164	—	—	—
Columbia	Macedonia (Gas-dist. field)	1*	—	(1) Cotton Valley	440	2.1	440	2.1	—	—
		* 1 Cotton Valley rework								
Columbia and Ouachita	Stephens (Smart area)	17*	62,386	(1) Tokio (16) Lower Cretaceous	270 2,384	— —	270 149	— —	— 8	— 26,580
		* 1 Tokio; 16 lower Glen Rose and "Travis Peak"								
Columbia	Village	1	7,404	(1) Smackover limestone	155	0.1	155	0.1	—	—
Lafayette	Buckner	1	7,316	(1) Smackover limestone	112	—	112	—	1	7,312
Lafayette	McKamie (Gas-dist. field)	1*	—	(1) Cotton Valley	335	0.9	335	0.9	—	—
		* 1 Cotton Valley rework								
Lafayette	Midway	32	207,139	(32) Smackover limestone	14,376	4.6	450	0.1	10	59,498
Lafayette	Patton	1	9,332	(1) Smackover limestone	320	0.5	320	0.5	—	—
Miller	Fouke	7	27,252	(7) Paluxy	1,617	—	230	—	2	8,077
Nevada	Troy	3*	3,296	(2) Nacatoch (1) Tokio	60 100	— —	30 100	— —	— —	— —
		* 2 Nacatoch; 1 DPN to Tokio								
Union	East El Dorado	1	2,904	(1) Nacatoch	40	—	40	—	—	—
Union	East Schuler	3*	11,687	(3) Cotton Valley	370	3.1	123	1.0	3	17,428
		* 1 Rework								
Union	El Dorado	—	—		—	—	—	—	2* * 1 DPN	3,755
Union	Hillsboro	9	20,146	(9) Nacatoch	216	—	24	—	—	—
Union	Mt. Holly	3	21,694	(3) Smackover limestone	405	1.9	135	0.6	1	7,318
Union	New London	9	53,513	(9) Cotton Valley	1,882	—	209	—	2	12,080
Union	Nick Springs	—	—		—	—	—	—	1	4,005
Union	Rainbow City	2	6,197	(2) Tokio	265	—	132	—	—	—
Union	Schuler	6*	—	(6) Cotton Valley	1,441	3.1	206	0.4	—	—
		* 6 Cotton Valley rework, including 1 dual Cotton Valley completion								
Union and Ouachita	Smackover*	2	4,749	(1) Nacatoch (1) Meekin	5 40	— —	5 40	— —	1 —	4,912 —
		* No record of reworked wells in Nacatoch and Meekin sands								
Union	Snow Hill	1*	62	(1) Smackover limestone * 1 DPN	19	—	19	—	—	—
Union	Urbana	—	—		—	—	—	—	1	3,591
Total		105	475,987						32	154,556

AVERAGE INITIALS—OIL

	Barrels
Nacatoch	25
Tokio	135
Paluxy	230
Lower Glen Rose and "Travis Peak"	150
Cotton Valley	220
Smackover	398

MM—1 million cubic feet of gas.
DPN—Deepening.
Dual—Dual completion; Smackover limestone and Cotton Valley.

COLUMBIA COUNTY

DORCHEAT FIELD (COTTON VALLEY SAND GAS-DISTILLATE AND OIL DISCOVERY)

SECS. 10, 13, 14, 15, AND 16, T. 18 S., R. 22 W.

The discovery well of Smackover limestone production in the Dorcheat field, the Atlantic Refining Company's Pinewood A1, Sec. 16, T. 18 S., R. 22 W., was completed, August, 1939, producing initially 21½ barrels per hour of 43.5° gravity oil with gas-oil ratio of 1,250/1.

TABLE VII

DRILLING ACTIVITIES IN SOUTH ARKANSAS GAS AND GAS DISTILLATE FIELDS DURING 1942

County	*Field*	*Gas and Gas Distillate Wells*							*Dry Holes*	
		No.	*Feet Drilled*		*Total Initial*		*Average Initial*		*No.*	*Feet Drilled*
					Bbls.	*MM*	*Bbls.*	*MM*		
Columbia	Big Creek	1	7,988	(1) Smackover limestone	55	1.0	55	1.0	—	—
Columbia	Columbia	1	8,116	(1) Smackover limestone	100	1.4	100	1.4	—	—
Columbia	Dorcheat	10*	62,719	(8) Cotton Valley	820	14.7	103	1.8	—	—
				(7) Smackover limestone	892	10.4	129	1.5	—	—
		* 2 Smackover limestone; 5 dual; 3 Cotton Valley rework								
Columbia	Macedonia	16*	124,951	(9) Cotton Valley	1,585	22.1	176	2.4	—	—
				(14) Smackover limestone	3,698	43.1	246	3.1	—	—
		* 7 Smackover limestone; 7 dual; 2 Cotton Valley rework								
Lafayette	McKamie	4	37,455	(4) Smackover limestone	1,361	9.2	340	2.3	2	19,262
Miller	Texarkana	1	7,700	(1) Smackover limestone	61	1.8	61	1.8	—	—
Union	Mt. Holly (oil field)	1	7,198	(1) Smackover limestone	37	0.4	37	0.4	—	—
Total		34*	256,127	(17) Cotton Valley					2	19,262
				(29) Smackover limestone						

* 17 Smackover limestone; 12 dual; 5 Cotton Valley rework

AVERAGE INITIALS—GAS DISTILLATE

Cotton Valley..... 141 Bbls. 2.1 MM.
Smackover..... 214 Bbls. 2.3 MM.

MM.—1 million cubic feet gas.
Dual—Dual completion. (Smackover limestone and Cotton Valley)

The discovery well of Cotton Valley gas-distillate production, the Atlantic Refining Company's Pinewood B1, Sec. 16, T. 18 S., R. 22 W., was completed in a sand occurring 1,290 feet below the top of the Cotton Valley formation and 995 feet above the top of the Smackover limestone. The B1 well, originally a Smackover limestone completion, went dead in October, 1941, was plugged back to 7,891 feet, reperforated between 7,860 and 7,875 feet with 36 shots, and recompleted on February 6, 1942, with an initial production of 72 barrels of distillate in 12 hours, flowing through a 16/64-inch tubing choke; casing pressure 2,500 pounds; tubing pressure 2,300 pounds; gas-oil ratio 15,000/1; gravity 65.6°.

During 1942, 7 gas-distillate wells were completed in the B1 sand. Four of the 7 wells were drilled and completed during the year as dual completions; two were Smackover limestone producers recompleted in the B1 sand as dual completions; one well, the B1 sand discovery well, was plugged back from the Smackover limestone and recompleted in the Cotton Valley.

A second Cotton Valley gas-distillate sand in the Dorcheat field was opened by the completion of the Magnolia Petroleum Company's E. P. Nipper No. 1, Sec. 14, T. 18 S., R. 22 W. The sand in the Nipper well is 530 feet below the top of the Cotton Valley forma-

TABLE VIII

SOUTH ARKANSAS WILDCAT DRY HOLES

County	*No.*	*Feet Drilled*	*County*	*No.*	*Feet Drilled*
Arkansas	1	1,390	Lafayette	4	30,910
Bradley	3	16,352	Little River	3	7,756
Calhoun	3	15,178	Miller	2	13,193
Clark	3	3,682	Nevada	2	8,083
Columbia	3*	17,964	Ouachita	6	18,654
* includes 1 DPN			Union	7	39,180
Hempstead	2	12,489		—	—
Jefferson	2	3,460	Total	41	188,291

TABLE IX

New Discoveries, 1942, in South Arkansas

Field Name	*County*	*Company and Farm*	*Location*	*Completion Date*	*Initial Production Bbls. per Day Gravity, Degrees*	*Pay Depth (Feet)*	*Formation*	*Total Depth (Feet)*
Midway	Lafayette	Barnsdall Oil Co. E. S. Bond 1	Sec. 11-15S-24W	1-1-1942	643 oil flowing; 36° GOR 257/1	Perf. csg. 6,340–70	Smackover ls. (Jurassic)	6,536
*Dorcheat	Columbia	Atlantic Ref. Co. Pine Woods Lbr. Co. B-1	Sec. 16-18S-22W	2-6-1942	6 BPH distillate, flowing; 65.6°. GOR 15,000/1	Re-perf. csg. 7,860–75 (Plug back to 7,891 from Smackover ls.)	Cotton Valley (Jurassic)	8,890
Dorcheat	Columbia	**C. F. & M. Prod. Co. Keith 1	Sec. 16-18S-22W	8-9-1942	147 bbls. oil flowing; GOR 850/1; 44°.	Perf. csg. 7,902–11	Cotton Valley (Jurassic)	8,913
		** Well originally drilled by Mid-Continent Pet. Co. Tested S.W. in Smackover lime and abandoned July 11, 1940						
†McKamie	Lafayette	Carter Oil Co. R. R. Cornelius Unit 1	Sec. 30-17S-23W	2-11-1942	14 BPH oil flowing; 46.2°; GOR 265/1	Re-perf. csg. 7,255–65 (Plug back to 7,280 from Smackover ls.)	Cotton Valley (Jurassic)	9,429
New London	Union	Marine Oil Co. Frost Lbr. Co. 1	Sec. 13-18S-12W	4-17-1942	80 oil flowing; 33°	Perf. csg. 5,760–70	Cotton Valley (Jurassic)	5,870
‡Macedonia	Columbia	J. K. Hughes Oil Co. Smith-Souter *et al.* 1	Sec. 21-18S-21W	8-22-1942	181 distillate flowing; 66°; GOR 14,000/1	Perf. csg. 8,054–66 (Dual completion—Cotton Valley and Smackover ls.)	Cotton Valley (Jurassic)	8,898
Texarkana	Miller	Carter Oil Co. L. E. Orr 1	Sec. 3-16S-28W	9-8-1942	61 distillate and 1.8 MM gas (sweet); 71.3° @ 60°F GOR 30,960/1	Perf. csg. 7,348–7,405	Smackover ls. (Jurassic)	7,700
Columbia	Columbia	Roy Lee, Trustee L. P. Pickler 1	Sec. 23-17S-21W	12-31-1942	100 distillate flowing; 68°; GOR, 14,000/1 (1/10 of 1% B.S. and water)	Perf. csg. 8,051–55	Smackover ls. (Jurassic)	8,116

BPH—Barrels per hour.
BS—Sediment and drilling mud from shake-out test of oil.
GOR—Gas-oil ratio.
Gravity of oil in degrees A.P.I.
* Dorcheat: discovery well completed August, 1939, in Smackover limestone.
† McKamie: discovery well completed June, 1940, in Smackover limestone.
‡ Macedonia: discovery well completed July, 1941, in Smackover limestone.

tion. The well was completed in September as a dual completion, producing from the Smackover limestone through perforations between 8,888 and 8,898 feet at an initial rate of 354 barrels of distillate daily, 62.2° gravity, and through perforations between 7,020 and 7,034 feet, with an initial of 46 barrels daily, flowing through ¼-inch tubing choke; casing pressure 400 pounds; gas-oil ratio 7913/1.

In July, 1940, the Mid-Continent Petroleum Company abandoned Keith No. 1, Sec. 16, T. 18 S., R. 22 W., as a dry hole in the Smackover limestone. This well was taken over and reworked by the C. F. & M. Production Company and was completed on August 9, 1942, through perforations between 7,902 and 7,911 feet at the initial rate of 147 barrels daily flowing through ⅛-inch tubing choke; tubing pressure 1,000 pounds; gas-oil ratio 850/1; gravity 44° A.P.I. The oil-producing sand of the Keith well is correlated with the gas-distillate sand of the Atlantic's Pinewood B1.

In addition to the listed dual and rework completions, two gas-distillate and one oil well were completed in the Smackover limestone during 1942. The total production of oil and distillate from 25 wells in the Dorcheat field during the year was 623,807 barrels. This figure includes production from both the Cotton Valley sands and the Smackover limestone. The Cotton Valley sand production for the year was approximately 52,300 barrels.

COLUMBIA COUNTY

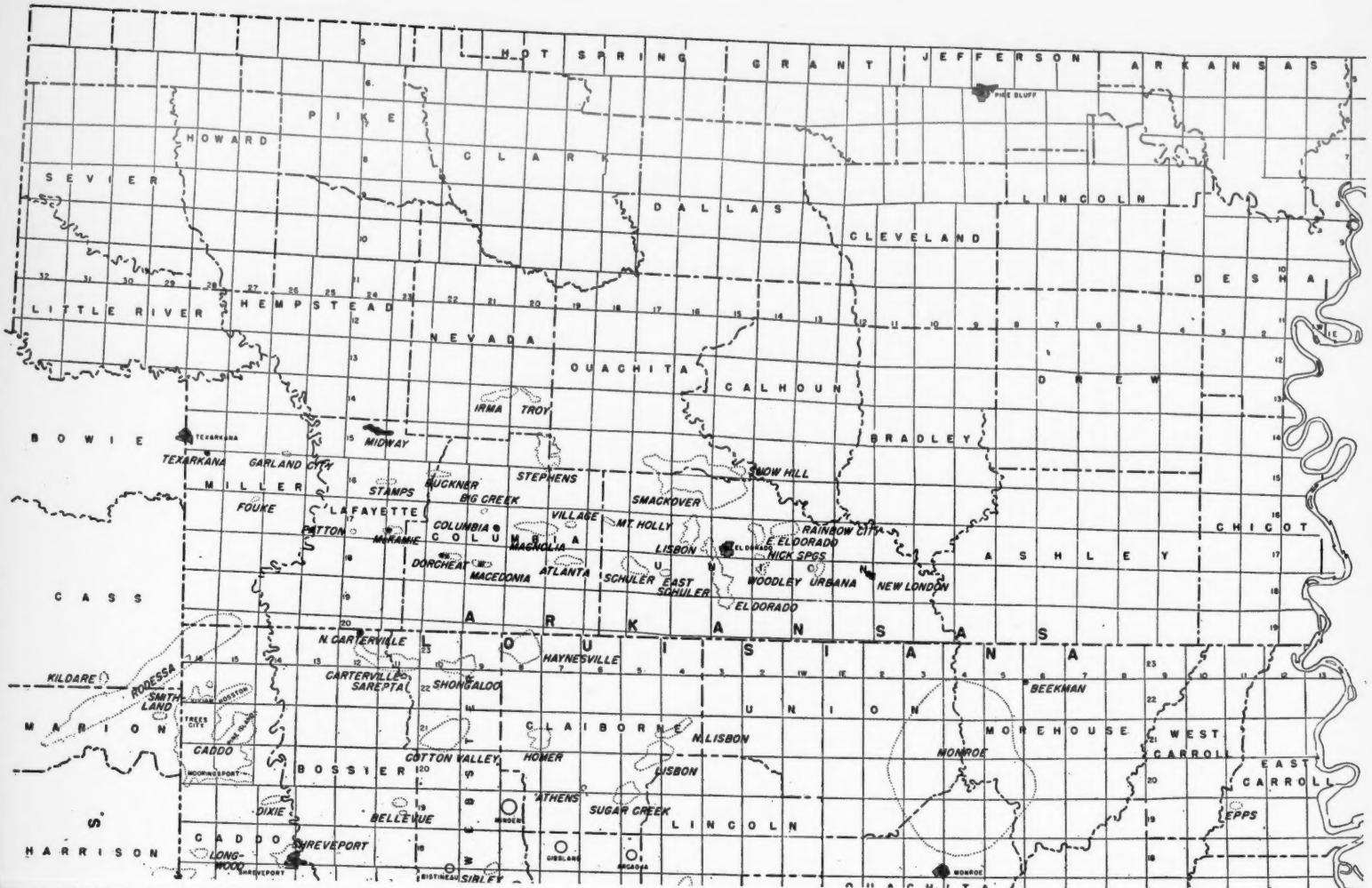
MACEDONIA FIELD (COTTON VALLEY SAND GAS-DISTILLATE AND OIL DISCOVERIES) SECS. 15, 16, 17, 20, 21, AND 22, T. 18 S., R. 21 W.

The discovery well of Smackover limestone gas-distillate production of the Macedonia field, the McAlester Fuel Oil Company's Franks A1, Sec. 16, T. 18 S., R. 21 W., was completed in July, 1941.

During 1942, Cotton Valley gas-distillate and oil production was developed in the Macedonia field. The discovery well, the J. K. Hughes Oil Company's Smith-Souter *et al.* No. 1, a gas-distillate well in Sec. 21, T. 18 S., R. 21 W., was completed, August 22, 1942, as a dual completion. Casing was gun-perforated between 8,858 and 8,870 feet with 47 shots in the top of the Smackover limestone and the well completed with an initial flow of 232 barrels of distillate in 24 hours through ¼-inch tubing choke; tubing pressure 2,550 pounds; gas-oil ratio 10,201/1; gravity 60°. Casing also was gun-perforated between depths of 8,054 and 8,066 feet with 20 shots opposite a sandstone in the Cotton Valley formation, and the well completed with an initial flow of 181 barrels of distillate in 24 hours through ¼-inch tubing choke; casing pressure 2,600 pounds; gas-oil ratio 14,000/1; gravity 66°. The top of the Cotton Valley formation was logged at 6,480 feet and the top of the Smackover limestone at 8,826 feet in the Hughes well. The gas-distillate sand is approximately 1,570 feet below the top of the Cotton Valley formation and 775 feet above the top of the Smackover limestone.

The Magnolia Petroleum Company's Franks-Norwood Unit No. 1, Sec. 16, T. 18 S., R. 21 W., was originally completed in November, 1941, as a gas-distillate producer from the Smackover limestone. During 1942, casing was reperforated between 7,800 and 7,810 feet with 47 shots opposite a sandstone in the Cotton Valley formation, and the well was recompleted, flowing 440 barrels of 44.9° gravity oil in 24 hours; gas-oil ratio 482/1. McAlester's L. Franks No. 1, in the same quarter section as the Magnolia well, was recompleted in the same sand, as a gas-distillate producer with an initial of 147 barrels of 59.4° gravity distillate in 24 hours; gas-oil ratio 11,860/1.

The productive Cotton Valley sands of the Macedonia field occur in a zone ranging from 1,220 to 1,760 feet below the top of the Cotton Valley formation. During the year, five productive sands were found in this zone; 4 wells were completed in the sand of the discovery well. During 1942 there were 7 Smackover limestone completions, 7 dual completions and 3 Cotton Valley rework completions in the Macedonia field. Total distillate and oil produced during 1942 from 19 wells was 392,680 barrels of which approximately 17,500 barrels were recovered from the Cotton Valley sands.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JEFFERSON
ARKANSAS
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HOWARD
CLARK
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LINCOLN
CLEVELAND
DESHA
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OUACHITA
CALHOUN
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BRADLEY
CHICOT
MILLER
LAFAYETTE
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CASS
LOUISIANA
MARION
UNION
CLAIBORNE
MOREHOUSE
WEST CARROLL
EAST CARROLL
BOSSIER
CADDO
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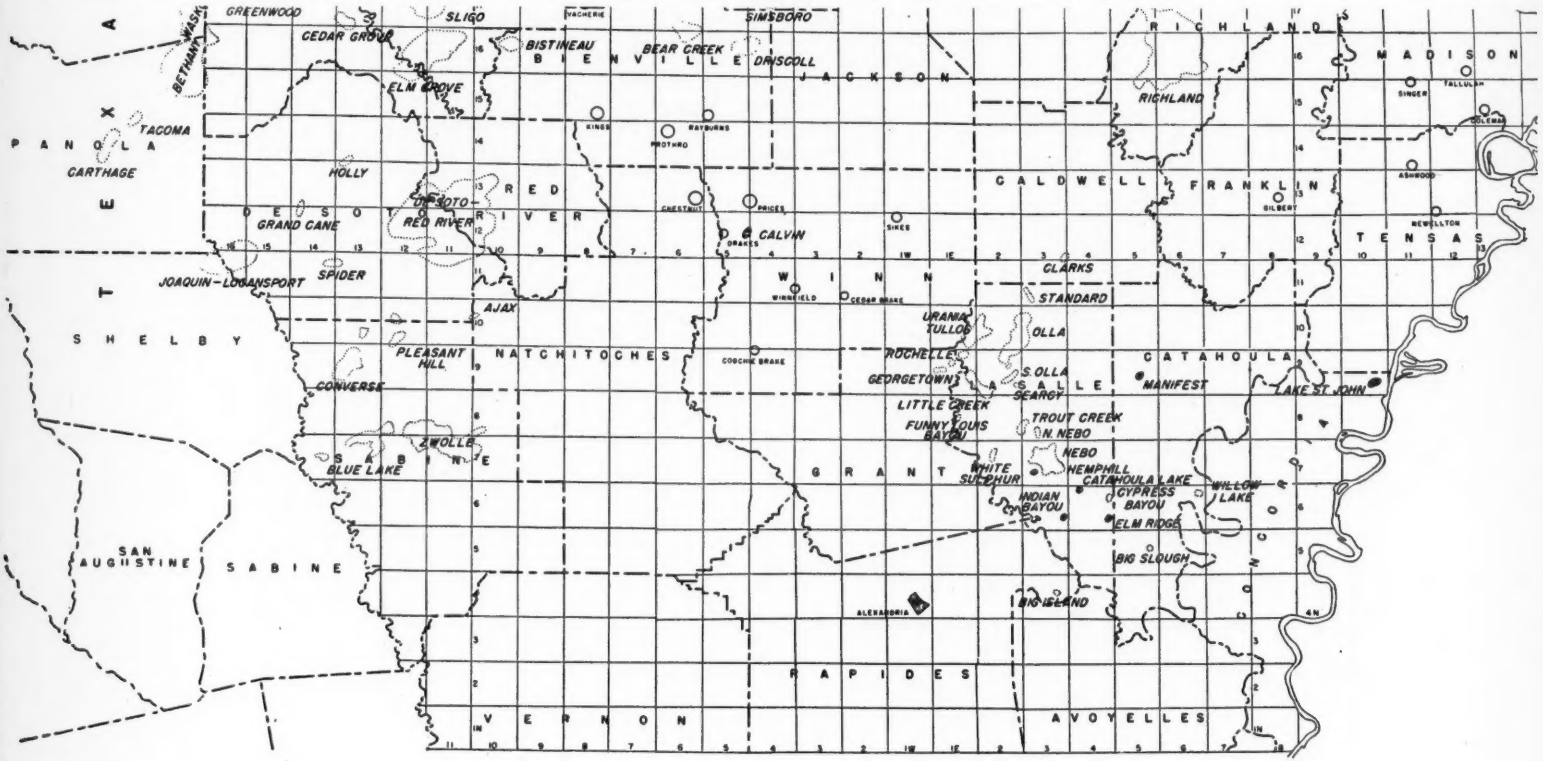

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SOUTH ARKANSAS & NORTH LOUISIANA
OIL, GAS DISTILLATE & GAS FIELDS

DISCOVERIES DURING 1942

- OIL FIELDS
- GAS DISTILLATE FIELDS
- GAS FIELDS

DISCOVERIES PRIOR TO 1942

- OIL, GAS DISTILLATE & GAS FIELDS
- SALT DOMES

LAFAYETTE COUNTY

MCKAMIE FIELD (COTTON VALLEY SAND OIL DISCOVERY)

SEC. 30, T. 17 S., R. 23 W.

The McKamie field was discovered in June, 1940, by the completion of the Atlantic Refining Company's Bodcaw Lumber Company No. 1, Sec. 29, T. 17 S., R. 23 W. The initial gauge of the discovery well was 20 barrels of distillate per hour, with gas-oil ratio of 8,300/1, from the Smackover limestone.

During 1942, Cotton Valley oil production was developed in the McKamie field The discovery well, the Carter Oil Company's R. R. Cornelius Unit No. 1, Sec. 30, T. 17 S., R. 23 W., was originally completed, July, 1941, as a Smackover limestone producer. As a result of salt-water encroachment in the Smackover limestone, it was plugged back to 7,280 feet, and casing was perforated between 7,255 and 7,265 feet with 20 shots. The well was recompleted, February 11, 1942, flowing 14 barrels of oil per hour through ¼-inch tubing choke on a 4-hour gauge; casing pressure 525 pounds; tubing pressure 300 pounds; gas-oil ratio 265/1; gravity 46.2°. The oil-producing sand occurs approximately 400 feet below the top of the Cotton Valley formation and 2,050 feet above the top of the Smackover limestone. By correlation, the oil sand occurs in the Morgan zone of the Schuler field.

Four Smackover limestone gas-distillate wells were completed during 1942 in the McKamie field, and two dry holes on the south flank of the structure.

The total oil and distillate production for 1942 was 723,686 barrels from 19 wells, of which amount approximately 15,600 barrels were produced by the Cotton Valley sand discovery well.

LAFAYETTE COUNTY

MIDWAY FIELD (SMACKOVER LIMESTONE OIL DISCOVERY)

SECS. 9–14, T. 15 S., R. 24 W., AND SEC. 18, T. 15 S., R. 23 W.

The most important discovery made in Arkansas in 1942 was the Midway field, 6 miles north of Lewisville, in the north part of Lafayette County.

The discovery well, the Barnsdall Oil Company's E. S. Bond No. 1, Sec. 11, T. 15 S., R. 24 W., was completed January 1, 1942, flowing 48 barrels per hour through 18/64-inch adjustable choke; tubing pressure 750 pounds; casing pressure 700 pounds; gas-oil ratio 240/1.[3] The daily production rate was 643 barrels through 15/64-inch tubing choke; casing pressure 750 pounds; tubing pressure 850 pounds; bottom-hole pressure 2,810 pounds; gas-oil ratio 257/1; A.P.I. gravity, sulphur-free oil 36°. The Bond well was drilled to the total depth of 6,536 feet; 7-inch casing was gun-perforated between 6,340 and 6,370 feet with 80 shots and between 6,350 and 6,370 feet with 20 shots. The oil-saturated porous Reynolds oölitic zone was logged between 6,340 and 6,372 feet. A second oil-saturated zone, the Bond zone,[4] was encountered between 6,419 and the total depth of the hole. The Bond zone is made up of granular, almost non-oölitic, highly porous and permeable limestones. The proved productive section of the Smackover limestone in the discovery well is the 68 feet of the Reynolds oölitic limestone; the probable productive section of 101–107 feet of the deeper Bond zone is untested.[5]

[3] E. A. Markley and Claude N. Valerius, "Midway Field Discovery, Lafayette County, Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 7 (July, 1942), pp. 1289–91.

[4] *Ibid.*

[5] *Ibid.*

The discovery well of the Midway field was located following detailed seismograph surveys. It is the highest well structurally on top of the Smackover limestone to date. Contoured on top of the Smackover limestone, the structure of the Midway field is an anticline, with approximately 200 feet of closure and with a northwest–southeast axial trend.

The following formational contacts were logged in the discovery well: top of Arkadelphia marl 915 feet; top Natcatoch sand 1,060 feet; top Saratoga chalk 1,438 feet; base of Annona chalk 1,770 feet; Buckrange sand (basal Taylor) 1,880–1,895 feet; top of Brownstown (top Austin) 1,895 feet; top first Tokio sand 2,005 feet; base Tokio (base Austin) 2,272 feet; Eagle Ford shale zone 2,272–2,310 feet; Lewisville volcanic zone 2,310–2,392 feet; Upper Cretaceous-Lower Cretaceous contact 2,392 feet; Ferry Lake (massive) anhydrite 3,140–3,268 feet; top James limestone 3,712 feet; top "Travis Peak" 4,025 feet; top Cotton Valley 4,898 feet; top Buckner 6,150 feet; dolomitic shale zone 6,299–6,304 feet; top Smackover limestone 6,304 feet; top Bond zone 6,419 feet. The oil-water contact occurs at the approximate subsea depth of −6,225 feet; in parts of the field it may be as low as −6,248 feet.

The average porosity of the Reynolds oölitic limestone is 24%; average permeability 350 millidarcys; percentage of connate water varies from 30% to 45%. As a rule, the highest porosities and permeabilities exist on the highest part of the structure. The average gas-oil ratio, from initials of 32 wells, is 312/1.

Thirty-two oil wells and 10 dry holes were completed in the Midway field during 1942. The proved area at the end of 1942 was 1,280 acres, with a 40-acre per well spacing. The total production at the end of 1942 was 1,215,304 barrels.

MILLER COUNTY

TEXARKANA FIELD (SMACKOVER LIMESTONE GAS-DISTILLATE DISCOVERY)

SEC. 3, T. 16 S., R. 28 W.

The discovery well of the Texarkana field, the Carter Oil Company's L. E. Orr No. 1, Sec. 3, T. 16 S., R. 28 W., was completed, September 8, 1942, in the Smackover limestone as a gas-distillate producer. It was drilled to the total depth of 7,700 feet. Six-inch casing was set at 7,500 feet and gun-perforated between 7,348 and 7,405 feet with 287 shots. The reported initial of the Orr well was 61 barrels of distillate and 1,800,000 cubic feet of sweet gas daily through ⅛-inch tubing choke; tubing pressure 2,590 pounds, tubing set on packer; gas-oil ratio 30,960/1; gravity of distillate 71.3° at 60° F. On a 5-hour gauge, through a 7/32-inch tubing choke set on packer at 7,334 feet, the well produced at the rate of 96 barrels of distillate with estimated 2,972,000 cubic feet of gas per day. Calculated heating value from separator gas was 623 B.T.U.; the gas is approximately 52% nitrogen by volume.

The Carter's Orr No. 1 is approximately 4 miles southeast of Texarkana. The location was made on a seismograph prospect; the estimated areal extent and amount of closure of the seismograph structure have not been reported. No further developments were made during 1942.

The following formation contacts were logged in the Orr well: top Arkadelphia chalk 860 feet; top Nacatoch sand 1,040 feet; top Saratoga chalk 1,522 feet; base Annona chalk 1,930 feet; Buckrange sand 1,995–2,015 feet; base Tokio-top Eagle Ford 2,440 feet; Lewisville volcanics 2,665–2,775 feet; Upper Cretaceous-Lower Cretaceous contact 2,775 feet (Lewisville volcanics resting on Paluxy); top Ferry Lake (massive) anhydrite 4,190 feet; base Ferry Lake anhydrite 4,295 feet; top James limestone 4,712 feet; top "Travis

Peak" 5,030 feet; top Cotton Valley 5,980 feet; top Buckner 7,112 feet; top Smackover limestone 7,342 feet; top redbeds 7,625 feet; salt was not reached at the total depth of 7,700 feet.

The total distillate production from the Orr well to the end of 1942 was 10,555 barrels.

UNION COUNTY

NEW LONDON FIELD (COTTON VALLEY SAND OIL DISCOVERY)

SECS. 12–13, T. 18 S., R. 12 W.

The discovery well of the New London field, the Marine Oil Company's Frost No. 1, Sec. 13, T. 18 S., R. 12 W., was completed, April 17, 1942, flowing 80 barrels of clean oil daily by heads through open tubing, set on packer; gravity 33°, shut-in pressure 400 pounds on tubing. The Frost well was drilled to 5,870 feet; 5½-inch casing was set at 5,863 feet and gun-perforated between 5,760 and 5,770 feet with 47 shots. The producing zone, the "Frost sand," occurs near the base of the Cotton Valley formation.

The New London field is 3½ miles southeast of New London, eastern Union County. It is 4½ miles northeast of Strong, the nearest railroad point.

In September, 1939, Joe Modisette's Union Saw Mill No. 3, Sec. 13, T. 18 S., R. 12 W., was completed as a dry hole in the Smackover limestone at the total depth of 6,291 feet. It was located on a seismograph prospect, closure of which was reported to approximate 50 feet on the top of the Smackover limestone. Examination of samples from this well showed that sandstones in the Cotton Valley formation, with oil saturation, had been encountered at several depths. The Cotton Valley sandstones were not tested by Modisette. Electrical survey was not made of the discovery well which was located within 100 feet of the Modisette test. The following contact depths were determined in Modisette's Union Saw Mill Company No. 3: top Arkadelphia 2,185 feet, top Nacatoch sand 2,210 feet, base Annona chalk 2,658 feet, Upper Cretaceous-Lower Cretaceous contact (Tokio gravelly sand resting on the Hosston formation) 2,858 feet, top Cotton Valley 3,928 feet, oil sand of discovery well 5,760–5,770 feet, top Buckner 6,025 feet, top Smackover limestone 6,056 feet.

The second completion in the New London field was the Marine Oil Company's Walton No. 1, Sec. 13, T. 18 S., R. 12 W., a west offset to the discovery well. It was completed June 15, 1942, flowing 150 barrels in 12 hours through ¼-inch tubing choke from gun-perforations between 5,716 and 5,728 feet; tubing pressure 250 pounds. The Walton well produces from a sandstone 65 feet higher stratigraphically than the Frost No. 1 sand of the discovery well. During 1942, 6 oil wells were completed in the Walton sand; one of these wells, the Marine Oil Company's Frost No. 2, Sec. 13, T. 18 S., R. 12 W., is a dual completion, being gun-perforated in the Walton sand and in the Frost No. 2 sand which is 15 feet below the Walton sand. The third productive sand of the field was discovered, August 30, 1942, by the completion of the Marine Oil Company's Frost No. 3, Sec. 12, T. 18 S., R. 12 W. Casing was gun-perforated between 5,844 and 5,850 feet in a sand 125 feet below the Walton sand. The Frost No. 3 was completed, flowing at the rate of 17 barrels per hour through 10/64-inch tubing choke; tubing pressure 425 pounds, tubing set on packer; gravity 31°. The second well completed in the Frost No. 3 sand, was the Marine Oil Company's Frost No. 4, an east offset to the Frost No. 3.

The subsurface structure of the New London field is probably a closed anticline with east-west axial trend. Developments during 1942 appeared to be located on the western part of the structure. The 9 oil-well completions during the year proved approximately 360 productive acres; 2 dry holes were located on the southwest edge of the field.

The total pipeline runs for the New London field to the end of 1942 were 60,421 barrels. Crude oil used for fuel in drilling operations was not reported.

SUMMARIZED DISCUSSION OF DISCOVERIES IN NORTH LOUISIANA IN 1942

BOSSIER PARISH

NORTH CARTERVILLE FIELD (PETTIT LIMESTONE OIL DISCOVERY)

SEC. 3, T. 23 N., R. 12 W.

The completion on December 15, 1942, of the Hunt Oil Company's Nebo Oil Company No. 1, Sec. 3, T. 23 N., R. 12 W., opened a new Pettit limestone producing area in northwest Louisiana. The discovery well is 2½ miles north of Carterville and 4¾ miles northwest of the Tokio sand oil-producing area of the old Carterville gas field. The newly discovered producing area is on the north flank of an east-west anticlinal structure as mapped on the base of the Ferry Lake (massive) anhydrite. The Carterville, the Haynesville, and the East Haynesville Lower Cretaceous structures appear to be localized features on an elongate regional structural ridge, the axis of which is located south of the Louisiana-Arkansas state line; the ridge extends approximately east and west for nearly 40 miles.

The discovery well was drilled to the total depth of 6,577 feet, into the Hosston formation. Five and one half-inch casing was set at 6,252 feet, and gun perforated between 6,029 and 6,122 feet with 366 shots.

After acid treatment with 5,000 gallons, the well was completed, flowing 164 barrels of oil daily with input gas through 2½-inch tubing; gravity 38°. The Pettit porous limestone member of the Sligo formation is exceptionally thick in Hunt's discovery well. This well was the second test drilled by the Hunt Oil Company, and was the third well to be drilled through the Pettit limestone in the Carterville area. The first Pettit limestone well in the area, the Magnolia Petroleum Company's Pardee C1, Sec. 17, T. 23 N., R. 11 W., with total depth of 10,070 feet, encountered Pettit limestone between 5,921 and 5,981 feet, of which 29 feet was slightly porous. The Pettit limestone in this well was made up of interbedded dense limestones and shales. A slight showing of oil was reported in the dense limestones. The second deep well in the area, the Hunt Oil Company's Bilbray No. 1, Sec. 5, T. 23 N., R. 11 W., is 1.2 miles north of the Magnolia well. The Pettit limestone was encountered between 5,938 and 6,005 feet and was made up of slightly porous limestones with a few shale streaks. Oil saturation was present in a core of fairly dense limestone at 5,957–5,964 feet. The Bilbray well was 9 feet lower structurally on top of the Pettit than the Magnolia Pardee well. Hunt's discovery well, 4 miles west of the Bilbray well, was 87 feet lower structurally on top of the Pettit than the Magnolia Pardee well.

The following formational contacts were logged in the Hunt Oil Company's Nebo Oil Company No. 1: top Upper Cretaceous chalk 1,637 feet; top Nacatoch sand 1,800 feet; top Saratoga chalk 2,218 feet; base Annona chalk 2,560 feet; top Blossom (Tokio) sand 2,715 feet; base Tokio-top Eagle Ford shale 3,250 feet; Upper Cretaceous-Lower Cretaceous contact 3,460 feet (Lewisville volcanic sands resting on Paluxy); base Ferry Lake (massive) anhydrite 5,087 feet; top James limestone 5,597 feet; top Three Finger limestone 5,981 feet; top Pettit limestone 6,029 feet; and top Hosston 6,220 feet.

The areal extent of the North Carterville Pettit limestone pool can not be forecast at this time.

CONCORDIA PARISH

LAKE ST. JOHN FIELD

SECS. 4, 13, 14, 15, AND 16, T. 9 N., R. 10 E.

The discovery well of the Lake St. John field, The California Company's Pan-American Life Insurance Company No. 1, Sec. 16, T. 9 N., R. 10 E., was completed, June 6, 1942, with initial production of 136 barrels of oil in 24 hours, flowing through 16/64-inch tubing choke; tubing pressure 125 pounds, tubing set on packer; gravity 44°; gas-oil ratio

TABLE X

Drilling Activities in North Louisiana Oil Fields during 1942

Parish	Field	Oil Wells: No.	Oil Wells: Feet Drilled	Oil Wells: Total Initial		Oil Wells: Average Initial		Gas and Gas Distillate Wells: No.	Gas and Gas Distillate Wells: Feet Drilled	Gas and Gas Distillate Wells: Total Initial		Gas and Gas Distillate Wells: Average Initial		Dry Holes: No.	Dry Holes: Feet Drilled
				Bbls.	MM	Bbls.	MM			Bbls.	MM	Bbls.	MM		
Bossier	Bellevue	1	406	(1) Nacatoch	5	—	5	—	1	390	—	3.0	—	3.0	3	11,988
Bossier	North Carterville	1	6,577	(1) Pettit	164	—	164	—	—	—	—	—	—	—	—	—
Bossier	Sligo	13	41,216	(13) Paluxy	586	—	45	—	—	—	—	—	—	—	1	3,180
Caddo	Caddo district	—	—		—	—	—	—	—	—	—	—	—	—	5	9,271
	Mooringsport															
	Pine Island	14	22,742	(14) Chalk rock	664	—	47	—	—	—	—	—	—	—	2	4,744
	Trees City	8	12,154	(5) Nacatoch	72	—	14	—	—	—	—	—	—	—	3	9,505
				(3) Paluxy	43	—	14	—	—	—	—	—	—	—	—	—
	Vivian	6	14,729	(6) Paluxy	1,152	—	192	—	—	—	—	—	—	—	9	23,040
Caddo	Dixie	1	2,506	(1) Paluxy	6	—	6	—	—	—	—	—	—	—	—	—
Caddo	Hosston	6	6,187	(6) Nacatoch	24	—	4	—	—	—	—	—	—	—	2	2,792
Caddo and Bossier	Shreveport	5	27,912	(5) Pettit	332	—	66	—	—	—	—	—	—	—	1	5,572
Catahoula	Big Slough (Larto Lake)	—	—		—	—	—	—	—	—	—	—	—	—	1	5,265
Catahoula	Manifest	1	4,554	(1) Sparta	49	—	49	—	—	—	—	—	—	—	1	1,756
Catahoula	Willow Lake	—	—		—	—	—	—	—	—	—	—	—	—	3	16,290
Claiborne	Athens	—	—		—	—	—	—	—	—	—	—	—	—	1	6,843
Claiborne	Haynesville	126	691,088	(126) Pettit	97,309*	36.5	772*	0.3	—	—	—	—	—	—	3	16,290
				* 24 hour estimates based on hourly gauges												
Claiborne	Homer	2	6,202	(1) Nacatoch	12	—	12	—	—	—	—	—	—	—	1	2,123
				(1) Blossom (Tokio)	60	—	60	—	—	—	—	—	—	—	—	—
Claiborne	Sugar Creek	2	11,979	(2) "Travis Peak"	830	—	415	—	3	18,040	(2) "Tr. Pk." gas	—	60.0	—	30.0	1	5,990
											(1) "Tr. Pk." gas-dist.	73	0.1	73	0.1	—	—
Concordia	Lake St. John	9*	47,751	(9) Wilcox	1,110	—	123	—	1	5,010	(1) Sparta	—	8.3	—	8.3	2	9,754
				* Includes California's Pan-Amer. No. 1, which was completed as Wilcox producer after testing gas-distillate in Tuscaloosa												
De Soto	Ajax	—	—		—	—	—	—	—	—		—	—	—	—	1	3,280
De Soto and Red River	De Soto-Red River	—	—		—	—	—	—	—	—		—	—	—	—	3	7,116
Grant	Rochelle	3	9,012	(3) Wilcox	102	—	34	—	—	—		—	—	—	—	2	5,662
La Salle	Catahoula Lake	2	10,295	(2) Wilcox	478	—	239	—	—	—		—	—	—	—	1	5,270
La Salle	Cypress Bayou	—	—		—	—	—	—	—	—		—	—	—	—	1	4,857
La Salle	Elm Ridge	1	5,976	(1) Wilcox	153	—	153	—	—	—		—	—	—	—	1	5,298
La Salle	Indian Bayou	1	5,905	(1) Wilcox	144	—	144	—	—	—		—	—	—	—	2	11,592
La Salle	Little Creek	18	47,323	(18) Wilcox	2,187	—	121	—	2	5,100	(2) Wilcox	—	3.0	—	1.5	5	15,895
La Salle	*Nebo	64	269,148	(2) Cockfield	34	—	17	—	—	—		—	—	—	—	12	51,455
				(62) Wilcox	8,468	—	137	—	1	4,085	(1) Wilcox	—	36.0	—	36.0	—	—
				* Nebo Field includes developments in Hemphill Area												
La Salle	North Nebo (South Jena)	—	—		—	—	—	—	—	—		—	—	—	—	3	12,188
La Salle	Olla	—	—		—	—	—	—	—	—		—	—	—	—	3	7,431
La Salle	South Olla (Summerville)	4	12,121	(4) Wilcox	372	—	93	—	—	—		—	—	—	—	3	9,939
La Salle	Trout Creek	4*	11,258	(4) Wilcox	486	—	121	—	—	—		—	—	—	—	5	19,142
				* 1 Rework												
Morehouse	Beekman	1	6,956	(1) Cotton Valley	35	1.5	35	1.5	—	—		—	—	—	—	1	3,918
Sabine	Converse	1	1,962	(1) Blossom (Tokio)	25	—	25	—	—	—		—	—	—	—	1	3,250
Sabine	Pleasant Hill	—	—		—	—	—	—	—	—		—	—	—	—	1	3,190
Sabine	Zwolle	—	—		—	—	—	—	—	—		—	—	—	—	1	2,577
Webster	Sarepta	1	2,700	(1) Blossom (Tokio)	9	—	9	—	—	—		—	—	—	—	2	5,367
Webster	Shongaloo	—	—		—	—	—	—	—	—		—	—	—	—	1	5,780
Total		295	1,278,659						8	32,625						88	317,610

AVERAGE INITIALS—OIL

	Barrels
Cockfield	17
Sparta	49
Wilcox	130
Nacatoch	9
Chalk Rock	47
Tokio	31
Paluxy	77
*Pettit	740
"Travis Peak"	415
Cotton Valley	35

* In Haynesville Pettit field estimated initials based on hourly gauges.
MM.—1 million cubic feet of gas.
"Tr. Pk."—"Travis Peak."

365/1. Casing was gun-perforated between 4,566 and 4,571 feet with 20 shots after plugging back to 4,609 feet from the total depth of 9,997 feet.

The Lake St. John oil field is 6 miles northeast of Clayton and is east of the crescentic Lake St. John, from which feature the field takes its name. The discovery Wilcox sand, designated as the 4,500-foot sand, is 1,165 feet below the top of the Wilcox. At the end of 1942, a total of 7 oil wells had been completed in this sand. During the year, two shallower Wilcox sands were found to be productive of oil, and one well was completed as a gas well in a sand at the top of the Claiborne Sparta formation.

The discovery well of the 3,500-foot sand, The California Company's Pan-American

TABLE XI

DRILLING ACTIVITIES IN NORTH LOUISIANA GAS AND GAS DISTILLATE FIELDS DURING 1942

Parish	Field	Gas and Gas Distillate Wells: No.	Feet Drilled		Total Initial: Bbls.	Total Initial: MM	Average Initial: Bbls.	Average Initial: MM	Dry Holes: No.	Dry Holes: Feet Drilled
Bienville	Bear Creek	1	7,248	(1) Pettit	—	11.5	—	11.5	—	—
Caddo	Bethany gas field (East flank)	—	—		—	—	—	—	1	6,305
Caldwell	Clarks	—	—		—	—	—	—	1	3,521
Claiborne	North Lisbon	5	50,897	(2) "Travis Peak"	—	75.0	—	37.5	1	5,300
				(2) Cotton Valley	37	0.5	18	0.2	—	—
				(1) Smackover limestone	198	4.0	198	4.0	—	—
De Soto	Logansport	3	14,950	(3) Rodessa zone	—	306.0	—	102.0	—	—
Morehouse and Union	Monroe	28	60,851	(28) Monroe gas rock	—	185.6	—	6.6	—	—
Webster	Cotton Valley	1	8,600	(1) Cotton Valley	515	7.2	515	7.2	—	—
Winn	Calvin	1	9,719	(1) Paluxy	70	2.1	70	2.1	—	—
Total		39	152,265						3	15,126
Gas-distillate		5								
Gas		34								

AVERAGE INITIALS—GAS DISTILLATE AND GAS

	Gas Distillate: Bbls.	Gas Distillate: MM	Gas: MM
Sparta	—	—	8.3
Wilcox	—	—	13.0
Monroe gas rock	—	—	6.6
Paluxy	70	2.1	—
Rodessa zone	—	—	102.0
Pettit	—	—	11.5
"Travis Peak"	73	0.1	34.0
Cotton Valley	184	2.6	—
Smackover limestone	198	4.0	—

MM.—1 million cubic feet of gas.

Life Insurance Company's No. 4, Sec. 15, T. 9 N., R. 10 E., was completed, July 31, 1942, flowing 130 barrels of oil in 24 hours through ¼-inch tubing choke; tubing pressure 825 pounds, tubing set on packer; gravity 34°; gas-oil ratio 500/1. The total depth was 4,620 feet. Seven-inch casing was set at 3,575 feet and gun-perforated between 3,482 and 3,522 feet with 150 shots. The top of the 3,500-foot sand is 103 feet below the top of the Wilcox. Only one well was completed in this sand during the year.

The discovery well of the 3,900-foot sand, The California Company's Applegate No. 4, Sec. 14, T. 9 N., R. 10 E., was completed, October 15, 1942, flowing 102 barrels of oil in 16 hours through 5/32-inch tubing choke; tubing pressure 650 pounds, tubing set on packer. This well was drilled to 4,680 feet and 5½-inch casing was set at 4,636 feet. The 4,500-foot sand tested salt water through perforations between 4,552 and 4,570 feet. Casing was reperforated between 3,925 and 3,930 feet with 22 shots. The top of the 3,900-foot sand is 580 feet below the top of the Wilcox. This was the only completion in this formation during the year.

E. C. Johnson's Brown No. 1, Sec. 4, T. 9 N., R. 10 E., was completed, October 16, 1942, as a gas well in a sand at the top of the Sparta formation. The well gauged 8,322,000 cubic feet of gas through ¾-inch tubing choke; estimated 26,000,000 cubic feet of gas, open flow; casing pressure 865 pounds; tubing pressure 684 pounds. This well was drilled to 5,010 feet. Cores of the 4,500-foot sand from 4,601–4,630 showed salt water. Five and one-half-inch casing was set 2,234 feet and gun-perforated between 2,131 and 2,139 feet with 24 shots. This was the only Sparta sand completion during the year. The Sparta sand gas well is 1¼ miles northeast of the nearest Wilcox sand oil well.

Prior to the completion of the discovery well of the Lake St. John field, the Carter Oil Company drilled a dry hole, early in 1942, in Sec. 29, T. 9 N., R. 10 E., less than 2 miles northwest of the producing area. A directional test which was drilled under Lake St. John from a location in Sec. 15, T. 9 N., R. 10 E., encountered salt water in the Wilcox sands. A well in Sec. 13, T. 9 N., R. 10 E., was abandoned at 3,201 feet because of a gas blow-out.

TABLE XII

NORTH LOUISIANA WILDCAT DRY HOLES

Parish	*No.*	*Feet Drilled*	*Parish*	*No.*	*Feet Drilled*
Bienville	3	12,774	Madison	4	17,882
Bossier	6	24,520	Natchitoches	4	24,116
Caddo	8	18,909	Rapides	1	5,755
Caldwell	4	16,546	Red River	3	9,420
Catahoula	15	96,073	Richland	2	8,512
Claiborne	5	31,576	Sabine	3	9,590
Concordia	3	20,630	Tensas	5	26,994
De Soto	2	5,014	Union	2	10,748
East Carroll	1	6,007	Webster	1	6,010
Grant	2	9,574	West Carroll	2	5,724
La Salle	13	67,921	Winn	4	20,072
Lincoln	1	6,878			
			Total	94	461,245

The California Company's Pan-American Life Insurance Company No. 1 discovery well of Wilcox sand production, was drilled to 9,997 feet, penetrating 1,050 feet of Lower Cretaceous beds. Casing was set at the total depth and gun-perforated between 9,815 and 9,835 feet with 24 shots. The formation tested, a sandstone in the Lower Glen Rose, contained salt water. Casing was reperforated between 8,935 and 8,946 feet with 21 shots, to test the basal sand of the Upper Cretaceous. On June 10, 1942, this sand tested 105 barrels of 60° gravity distillate in 24 hours, with an estimated 2 million cubic feet of gas. After several production tests in this sand, the well was mudded off and 7-inch casing was cut and pulled at 4,617 feet. A cement retainer was set inside the 9⅝-inch casing at 4,609 feet, and the well was recompleted in the 4,500-foot Wilcox sand on June 21, 1942.

Following are depths of contacts in the Pan-American well: base Moody's marl 1,370 feet; top Sparta 2,135 feet; top Wilcox 3,391 feet; top Midway shale 6,252 feet; top Upper Cretaceous (Saratoga chalk) 7,183 feet; base Annona chalk 7,405 feet; Ector tongue of Austin chalk 7,740–8,000 feet; top Eagle Ford 8,000 feet; Volcanic sand and redbed zone (middle Tuscaloosa) 8,155–8,555 feet; lower Eagle Ford shale (lower Tuscaloosa marine shale) 8,555–8,920 feet; basal Eagle Ford sand (gas-distillate sand: equivalent to basal massive sand of Tuscaloosa) 8,920–8,946 feet; Upper Cretaceous-Lower Cretaceous contact, with basal sand of Upper Cretaceous resting on Upper Glen Rose, 8,946 feet; base of Glen Rose massive anhydrite zone 9,500 feet; total depth 9,997 feet, in Lower Glen Rose.

The Lake St. John field is on a minimal gravity anomaly. The subsurface structure of the field as mapped on top of the Wilcox shows a possible closure of 50 or 60 feet. The

amount of structural closure increases with depth. The closure indicated on the top of the 4,500-foot oil sand is approximately 85 feet. It is probable that a deep salt dome underlies the Lake St. John structure.

A 40-acre spacing program is used in the field. Approximately 360 acres have been proved oil productive in the Wilcox sands to the end of 1942. The total production to the end of 1942 was 61,607 barrels from 9 wells.

CATAHOULA PARISH

MANIFEST FIELD (SPARTA SAND OIL DISCOVERY)

SEC. 22, T. 9 N., R. 5 E.

Eugene Jordan's Louisiana Central Lumber Company No. 1, Sec. 22, T. 9 N., R. 5 E., discovery well of the Manifest field, was completed, November 11, 1942, as an oil producer from the top of the Sparta sand. The Manifest discovery is the first Sparta sand (lower Claiborne) production found in the central part of North Louisiana. The discovery well is 7 miles southwest of Harrisonburg, parish seat of Catahoula Parish. The Jordan well was drilled to 4,554 feet, penetrating 1,632 feet of Wilcox. No oil showings were found in numerous side-wall cores taken in the Wilcox. Five and one half-inch casing was set at 1,858 feet and gun-perforated between 1,810 and 1,817 feet with 27 shots. The well was completed, pumping 70 barrels of fluid daily, 30% salt water. The gravity of the oil is 20°. During December, an offset on the northwest was drilled by the same operator. It was dry and abandoned at 1,756 feet, in the Sparta sand. The total production at the end of 1942 from the one well in the Manifest field was 1,291 barrels.

LA SALLE PARISH

CATAHOULA LAKE FIELD (WILCOX SAND OIL DISCOVERY)

SECS. 5–6, T. 6 N., R. 4 E.

The discovery well of the Catahoula Lake field, the Carter Oil Company *et al.* Catahoula Lake A1, Sec. 5, T. 6 N., R. 4 E., was completed as a Wilcox sand producer, April 14, 1942, pumping 64 barrels of oil and 96 barrels of salt water in 24 hours; gravity of oil 38.5°. Production was encountered in a sandstone 1,334 feet below the top of the Wilcox formation. The discovery well was drilled to 5,490 feet, into the Midway. It was plugged back to 4,303 feet, and casing was gun-perforated between 4,084 and 4,089 feet with 25 shots, and between 4,089 and 4,092 feet with 40 shots.

The Carter discovery well is in Catahoula Lake, more than a mile from its southeast shore; it is approximately 3¼ miles southeast of the nearest producing well in the Nebo field. A dry hole, the Carter Oil Company *et al.* Catahoula Lake C1, Sec. 36, T. 7 N., R. 3 E., 1¾ miles northwest of the oil well, was 102 feet higher structurally on top of the Wilcox and tested salt water in the producing sand of the discovery well. This dry hole is midway between the south limit of the Nebo field and the discovery well of the Lake Catahoula field.

The Carter Oil Company's Catahoula Lake C2, the second oil producer in the Catahoula Lake field, is in Sec. 6, T. 6 N., R. 4 E., ½ mile southwest of the discovery well. It was completed, September 8, 1942, in the same sand, flowing 449 barrels of fluid daily, 8% salt water, through 14/64-inch tubing choke; casing pressure 600 pounds; tubing pressure 800 pounds. Casing was gun-perforated between 4,090 and 4,094 feet with 20 shots. The second completion is 17 feet higher structurally on top of the Wilcox than the discovery well, and is 6 feet higher structurally on top of the producing oil sand. The total production at the end of 1942 from the Catahoula Lake field was 14,544 barrels.

TABLE XIII

New Discoveries, 1942, in North Louisiana

Field Name	*Parish*	*Company and Farm*	*Location*	*Completion Date*	*Initial Production Bbls. per Day Gravity, Degrees*	*Pay Depth (Feet)*	*Formation*	*Total Depth (Feet)*
Indian Bayou	La Salle	Carter Oil Co. Tensas Delta D-1	Sec. 25-6N-3E	1-4-42	144 oil flowing; 43.6° GOR 450/1	Perf. csg. 4,294–98	Wilcox (Eocene)	5,905
*Nebo	La Salle	H. L. Hunt Good Pine Oil Co. F-123	Sec. 29-7N-3E	2-25-42	25 fluid pumping 2% SW; 19.2°	Perf. csg. 1,420–28 and 1,430–35	Cockfield (Eocene)	5,395
Catahoula Lake	La Salle	Carter Oil Co. Catahoula Lake A-1	Sec. 5-6N-4E	4-14-42	64 oil and 96 SW., pumping; 38.5°	Perf. csg. 4,084–92	Wilcox (Eocene)	5,490
Lake St. John	Concordia	*The California Co. Pan-Am. Life Ins. Co. 1	Sec. 16-9N-10E	6-10-42	105 distillate flowing; 60°. Est. 2 MM cu. ft. gas	Perf. csg. 8,935–46	Tuscaloosa (Upper Cretaceous)	9,997
		* Well was completed in Wilcox sand after testing gas-distillate in Tuscaloosa sand						
Lake St. John	Concordia	The California Co. Pan-Am. Life Ins. Co. 1	Sec. 16-9N-10E	6-21-42	136 oil flowing; 44° GOR 365/1	P. B. to 4,609 Perf. csg. 4,566–71	Wilcox (Eocene)	9,997
Beekman	Morehouse	Union Prod. Co. Crossett Tbr. & Dev. Co. A-1	Sec. 6-22N-6E	9-28-42	25 oil and 20 SW in 17 hrs.; flowing with est. 1.5 MM cu. ft. gas; 46.0°	Perf. csg. 3,700–11	Cotton Valley (Jurassic)	6,056
Calvin	Winn	H. L. Hunt Goodpine Oil Co. F-24	Sec. 13-12N-5W	10-9-42	70 distillate and 2.1 MM cu. ft. gas; GOR 30,000/1	Perf. csg. 5,786–94	Paluxy (Lower Cretaceous)	9,719
Lake St. John	Concordia	E. C. Johnston Brown 1	Sec. 4-9N-10E	10-16-42	8,322,000 cu. ft. gas	Perf. csg. 2,131–39	Sparta (Eocene)	5,010
Elm Ridge	La Salle	Carter Oil Co., *et al.* Tensas Delta A-2	Sec. 25-6N-4E	10-21-42	174 fluid flowing; 12% BS and water; 45°	Perf. csg. 4,595–4,600 and 4,572–75	Wilcox (Eocene)	5,976
Manifest	Catahoula	E. Jordan La Central 1	Sec. 22-9N-5E	11-11-42	70 fluid pumping 30% SW; 20°	Perf. csg. 1,810–17	Sparta (Eocene)	4,554
North Carterville	Bossier	Hunt Oil Co. Nebo Oil Co. 1	Sec. 3-23N-12W	12-15-42	164 oil flowing with input gas; 38°	Perf. csg. 6,120–6,122	Pettit (Lower Cretaceous)	6,577

BS—Sediment and drilling mud from shake-out test.
GOR—Gas-oil ratio.
Gravity of oil in degrees A.P.I.
SW—Salt water.
P.B.—Plugged back.
* Nebo: discovery well completed September, 1940, in Wilcox.

LA SALLE PARISH

ELM RIDGE FIELD (WILCOX SAND OIL DISCOVERY)

SEC. 25, T. 6 N., R. 4 E.

The Carter Oil Company *et al.* Tensas Delta A2, Sec. 25, T. 6 N., R. 4 E., was completed, October 21, 1942, as an oil producer from a sandstone encountered 1,303 feet below the top of the Wilcox. This discovery is 3¼ miles south of the Cypress Bayou field and 6 miles east of the Indian Bayou field. It was drilled to 5,976 feet, into the Midway shale. Six-inch casing was set at 4,846 feet and gun-perforated from 4,572 to 4,575 feet with 15 shots, and from 4,595 to 4,600 feet with 24 shots. It was completed, flowing 174 barrels of fluid in 24 hours through 12/64-inch tubing choke, 12% sediment and water; casing pressure 600 pounds; tubing pressure 300 pounds; gas-oil ratio 363/1; gravity 45°.

A southwest diagonal offset test to the discovery well, the Carter Oil Company's Tensas Delta A3, Sec. 36, T. 6 N., R. 4 E., was dry and abandoned, November 11, 1942, in the Wilcox at the total depth of 5,298 feet. Structurally, on top of the oil sand, the dry hole was 10 feet lower than the oil well.

During 1941, prior to the completion of the discovery well, the Carter and Phillips jointly drilled two near-by dry holes. The Tensas Delta G1, Sec. 30, T. 6 N., R. 5 E., is one mile northeast of the discovery and the Tensas Delta Land Company No. 1, Sec. 27, T. 6 N., R. 4 E., is 1¾ miles west of the discovery.

The total production at the end of 1942 from the one well in the Elm Ridge field was 3,983 barrels.

LA SALLE PARISH

INDIAN BAYOU FIELD (WILCOX SAND OIL DISCOVERY)

SEC. 25, T. 6 N., R. 3 E.

The discovery well of the Indian Bayou field, the Carter Oil Company's Tensas Delta No. 1, Sec. 25, T. 6 N., R. 3 E., was completed, January 4, 1942. The well was drilled to 5,905 feet, into the Midway shale. Six-inch casing was set at 4,364 feet and gun-perforated between 4,294 and 4,298 feet with 20 shots. It was completed, flowing 144 barrels of 43.6° gravity oil in 24 hours through 10/64-inch tubing choke; casing pressure 800 pounds; tubing pressure 500 pounds; gas-oil ratio 450/1. The producing sand was encountered 1,351 feet below the top of the Wilcox formation.

It appears that the productive area of the Indian Bayou field will be small since two dry holes were drilled during 1942. The accumulation of oil does not appear to be controlled by structural closure since the dry hole ½ mile due west of the discovery well encountered the oil sand of the discovery well 44 feet higher structurally. The second dry hole, a diagonal northeast offset, encountered the sand 24 feet lower structurally than the oil well. A south offset location was abandoned. The discovery well produced 35,135 barrels during 1942.

LA SALLE PARISH

NEBO OIL FIELD (COCKFIELD SAND OIL DISCOVERY)

SECS. 28–29, T. 7 N., R. 3 E.

H. L. Hunt's Good Pine Oil Company F123, Sec. 29, T. 7 N., R. 3 E., was completed, February 15, 1942, pumping 25 barrels of fluid daily, 2% salt water, from a sandstone in the Claiborne Cockfield formation. The gravity of the oil was 19.2°. The F123 well was drilled to the total depth of 5,395 feet. Seven-inch casing was set at 2,675 feet and gun-perforated from 1,420 to 1,428 feet with 10 shots, and from 1,430 to 1,435 feet with 11 shots.

At the time of completion of the well, it was 1½ miles southwest of the nearest Wilcox sand producer of the Nebo field. At the end of 1942, the southwest limit of Wilcox sand

production had advanced within ¾ mile of the Cockfield sand discovery well. It is reported that the top of the Wilcox was encountered at 2,590 feet in the F123 well. The producing oil sand probably occurs near the middle part of the Cockfield formation.

H. L. Hunt's F119, Sec. 28, T. 7 N., R. 3 E., ½ mile northeast of the Cockfield sand discovery well in Sec. 27, was completed, September 10, 1942, as a 10-barrel pumper with 3% salt water, after testing salt water in the Wilcox sands. The producing sand was encountered between 1,392 and 1,422 feet, with the top of the sand 282 feet below the top of the Cockfield formation.

The areal extent of the Cockfield sand production on the southwest flank of the Nebo field can not be forecast at this time. Oil-production figures for 1942 are not available for the two Cockfield sand wells.

MOREHOUSE PARISH

BEEKMAN FIELD (COTTON VALLEY SAND OIL DISCOVERY)
SEC. 6, T. 22 N., R. 6 E.

The Union Producing Company's Crossett Timber and Development Company 1A, Sec. 6, T. 22 N., R. 6 E., was completed, September 28, 1942, as a small oil well in a sandstone between 3,700 and 3,730 feet. The top of the oil sand was encountered 277 feet below the top of the Cotton Valley formation. Casing was first gun-perforated with 55 shots between 3,700 and 3,711 feet. An unsuccessful completion necessitated additional gun perforating and squeeze jobs. On initial gauge the well flowed 25 barrels of oil and 20 barrels of salt water in 17 hours through ¼-inch tubing choke; casing pressure 1,350 pounds; tubing pressure 1,100 pounds; estimated 1,500,000 cubic feet of gas daily; gravity of oil 46°.

The Crossett well was drilled to 6,956 feet, penetrating 4 feet of salt. The Smackover limestone was encountered at 6,170 feet; the upper few feet were fairly porous oölitic limestone and dense, hard, sandy oölitic limestone; a drill-stem test showed salt water in the top. The following formation contacts were logged: top Wilcox 1,418 feet; top Midway 1,904 feet; top Monroe gas rock 2,438 feet; top Hosston 2,660 feet (Monroe gas rock of Upper Cretaceous age rests unconformably on Hosston); top Cotton Valley 3,423 feet; top Smackover limestone 6,170 feet; top salt 6,952 feet. Cores of the basal Cotton Valley between 6,160 and 6,168 feet were oil-stained pebbly sandstones.

The Union Producing Company's Crossett Timber and Development Company A2, Sec. 5, T. 22 N., R. 6 E., 1 mile east of the discovery oil well, the second test drilled in the area, did not find the producing sand of the discovery well, and was abandoned at the total depth of 3,918 feet, in the Cotton Valley formation. The second test was 21 feet lower structurally on the top of the Monroe gas rock than the discovery well, and 4 feet higher on the top of the Cotton Valley.

The Beekman discovery well is 11 miles east of the deep Union Producing Company's Tensas Delta A1 in Sec. 8, T. 22 N., R. 4 E., which was drilled to the total depth of 10,475 feet, into the Morehouse formation. In the Union's Tensas Delta A1, the top of the Smackover limestone was encountered at 7,230 feet; top of the Salt at 8,114 feet; and top of the Morehouse formation at 9,285 feet. The top of the Smackover limestone in the Crossett well is 1,121 feet higher structurally than in the Tensas Delta A1.

The stratigraphic unit of 1,190 feet of dark silty shales and thin siltstones penetrated in the Tensas Delta well was named the Morehouse formation. Imlay[6] tentatively assigned the Morehouse formation to the Jurassic, on the basis of a sponge which appeared to be related to described species from the Jurassic. During April, 1942, Imlay had opportunity for a detailed examination of cores of the Morehouse formation from the Tensas Delta

[6] Ralph W. Imlay, "Jurassic Fossils from Arkansas, Louisiana and Eastern Texas," *Jour. Paleon.*, Vol. 15, No. 3 (1941), pp. 261, 262.

well and collected about 50 species of pelecypods and gastropods. A distinctive gastropod and the general resemblances of the pelecypods suggest that the Morehouse shale is late Paleozoic in age, probably not older than Pennsylvanian.[7]

The total production for 1942 from the one well in the Beekman field was reported to have been 600 barrels.

WINN PARISH

CALVIN FIELD (PALUXY GAS-DISTILLATE DISCOVERY)

SEC. 13, T. 12 N., R. 5 W.

H. L. Hunt's Good Pine Oil Company F24, Sec. 13, T. 12 N., R. 5 W., discovery well of the Calvin field, was completed, October 9, 1942, as a gas-distillate producer in a sandstone 950 feet below the top of the Paluxy. Casing was gun-perforated from 5,786 to 5,794 feet with 32 shots. The initial gauge was 2,100,000 cubic feet of gas and 70 barrels of distillate daily through $\frac{1}{4}$-inch tubing choke; casing pressure 2,000 pounds; tubing pressure 1,875 pounds; gas-oil ratio 30,000/1; calculated open flow 9,500,000 cubic feet daily. The Hunt well is $4\frac{1}{2}$ miles northwest of Calvin. It is 4 miles south of Prices salt dome and 3 miles northeast of Drakes salt dome. It is reported that detailed seismograph work indicated the existence of a favorable Lower Cretaceous structural feature.

The discovery well of the Calvin field is particularly interesting since it is the first deep well located in the south part of the North Louisiana Salt Dome basin which has drilled into the Hosston formation. This discovery has opened an extensive area for future prospecting. The discovery well was the only well completed in the Calvin field during 1942. Except for a few days testing time, it has been closed since discovery. Total production of distillate at the end of 1942 was 284 barrels.

[7] Ralph W. Imlay and J. S. Williams, "Late Paleozoic Age of Morehouse Formation of Northeastern Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 10 (1942), p. 1672.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 2 (FEBRUARY, 1944), PP. 278-282

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

OIL AND GAS IN MIDDLE TENNESSEE (MAP), BY KENDALL E. BORN

REVIEW BY ARTHUR C. McFARLAN[1]
Lexington, Kentucky

"Oil and Gas in Middle Tennessee with Map of Pools, Columnar Section, Table of Data, and History of Developments," by Kendall E. Born. Tennessee Department of Conservation, Division of Geology (Nashville, 1943). Paper sheet, 34×22 inches.

Production of oil in Tennessee to date is less than a million barrels in spite of early discoveries dating back to 1866. Most of it is relatively shallow and much of it short-lived. About 40 per cent is Mississippian from the northern part of the Cumberland Plateau and vicinity, and is found in limestones at a number of stratigraphic levels. Most of the balance is Ordovician from near-by counties in the Highland Rim along the axis of the Cincinnati arch. This is a southern extension of the Cumberland River field of Cumberland, Clinton, and Monroe counties, Kentucky, with its often flashy, though in most pools short-lived, wells. Production has come from many zones ranging from Stones River to Trenton, and a little near-commercial oil has been found in sandy zones in the upper Knox. A particularly worthwhile analysis of the geology of this field is found in Born and Burwell's 1939 Report on Clay County, Tennessee.

The author recognizes the Cumberland Plateau and Highland Rim as favorable provinces, and the region west of the Tennessee River with its Cretaceous and Tertiary blanket as a possible province, all rating further exploration. "Corniferous" production in the Bowling Green field of Warren, Allen, and other counties, Kentucky, has not been extended across the line into Tennessee, and it seems to the writer that adjoining points of Tennessee on the southwest would have some merit. The whole problem here, though, is tied up with the pre-Chattanooga folding and the mid-Devonian and Chattanooga overlap. Possible deep production from the St. Peter (?) and upper Knox is still problematic.

In this map with its accompanying notes, the author supplies a very useful summary of the oil and gas situation involving general geology, structure, stratigraphy, and many pertinent oil and gas data. It gives one interested in exploration the basic facts necessary to get his feet on the ground in the shortest possible time.

[1] University of Kentucky. Manuscript received, December 18, 1943.

THE STRATIGRAPHY OF THE TERTIARY MARINE ROCKS IN GIPPSLAND, VICTORIA, BY IRENE CRESPIN

REVIEW BY BURTON WALLACE COLLINS[1]
Auckland, New Zealand

"The Stratigraphy of the Tertiary Marine Rocks in Gippsland, Victoria," by Irene Crespin, commonwealth paleontologist. *Commonwealth of Australia, Department of Supply and Shipping, Mineral Resources Survey, Palaeontological Bulletin 4* (Canberra, August 10, 1943). iii+101 pp., 7 maps, and plate of stratigraphic sections of bores.

[1] P.O. Box 10, Auckland, New Zealand. Manuscript received, January 10, 1944.

All Australasian geologists and many petroleum geologists throughout the world should find much to interest them in this remarkably fine publication of Miss Crespin's. The amount of work entailed in the lithologic and paleontologic examination of hundreds, if not thousands, of samples from bores and outcrops, and in correlating the vast amount of information obtained must have been enormous. Miss Crespin is certainly to be congratulated, not only on the work itself but also on the clarity and conciseness with which it is presented to her readers. As an indication of the amount of work involved it may be mentioned that this paper presents the results of investigation of cores from 71 bores, representing more than 92,000 feet of drilling, and of numerous surface sections; the 25-page fossil-distribution chart with which the paper concludes contains the names of 1,280 fossils (405 foraminifera, 307 bryozoa, 402 mollusca, 72 ostracoda, and smaller numbers of sponges, corals, worms, echinoderms, brachiopods, barnacles, crabs and fishes).

The scope of the paper and a few of the most interesting points raised by Miss Crespin's work may be appreciated from the following quotations from the foreword by H. G. Raggatt, director of the Commonwealth Mineral Resources Survey.

> Most of the information used in it [the paper] has been obtained as a result of scout drilling jointly by the Victorian and Commonwealth Governments and of wildcat drilling by private companies . . . the results cannot fail to have an important bearing on the stratigraphy of the Tertiary rocks in the Australasian region and this in turn will facilitate the study of problems involving palaeogeography and correlation with extra-Australian areas. The results will also have an important bearing on a major economic problem—the search for oil in Australia. . . .
>
> The suspension of exploratory drilling while the Lakes Entrance shaft is being sunk, presents a convenient opportunity of reviewing past results, as has been done in this Bulletin.
>
> Planning a work of this scope inevitably led to a review of the whole question of stratigraphical nomenclature. There is no thoroughly satisfactory system of classification and nomenclature of rock units, but the one put forward by the American Association of Petroleum Geologists in July, 1939, goes nearest to satisfying most requirements. The adoption of this system requires the use of "formation" and "group" in senses foreign to normal English and Australian usage, but this is a small matter compared with the advantages gained. . . .
>
> The terms "stage" and "substage," which are not used in the A.A.P.G. scheme, are well established in Australian literature generally [also in New Zealand—B. W. C.] and are very commonly used all over the world (especially in descriptions of Tertiary stratigraphy) and to attempt to abandon them would cause confusion. Moreover, it is useful to have time units of lower rank than series for purposes of correlation and this can be done without difficulty as has been shown by Kleinpell (1938) and Schenck and Muller (1941). The procedure adopted by these authors has been followed closely in this Bulletin . . . .
>
> The issuing of this Bulletin follows upon the publication of F. A. Singleton's "Tertiary Geology of Australia" (1941)[2] . . . it is not surprising that there should be some significant differences between Dr. Singleton's account of the Tertiary sequence and that given by Miss Crespin for the Gippsland basin. These are briefly:
>
> "The Cheltenhamian stage (of Singleton) is considered to be a facies of the Kalimnan, but a new stage (Mitchellian) is described overlying the Balcombian and underlying the Kalimnan.
>
> "The Balcombian is recognised by Miss Crespin as a stage but the Batesfordian is not; the Batesford is shown to be only a substage of the Balcombian. This substage together with the Bairnsdale and Longford substages, both newly defined herein, make up the Balcombian as now described. . . ."
>
> Miss Crespin shows that the faunas of the Anglesean, Janjukian and Balcombian stages are closely related; and she regards all of these as stages of the Middle Miocene.
>
> Because of the necessity of presenting results in the most economical way possible during wartime, this publication is issued in roneoed [duplicated] form. This method has imposed some unavoidable restrictions on the presentation of the distribution list of fossils, but it is hoped that after the war this Bulletin will be printed in the form of previous publications in this series.

The paper is divided into 14 parts, and some of the topics appearing in the headings, with brief notes by the reviewer, follow.

Introduction.—Presence of oil first proved in Lakes Entrance area, Gippsland, in 1924, but intensive drilling not begun for some years. Until recently stratigraphic stages in Victorian sequence based primarily on mollusca, but zoning of Gippsland Tertiaries determined by Miss Crespin in this paper mainly by foraminifera.

[2] Reviewed in *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 9 (September, 1941).

Classification and stratigraphic nomenclature.—Defines new units and redefines others, as mentioned in extracts from foreword quoted above. Defines four formations.

Position of Lepidocyclina horizon and age of beds.—Lepidocyclinae occur only in the Batesford substage of the Balcombian; show close relationship with Indo-Pacific region; belong to upper portion of the middle Miocene, upper part of stage "f" of East Indies Tertiary.

Stratigraphic succession.—The stratigraphic sequence of the marine Tertiary rocks in Gippsland is divided as follows.

Series	*Stage*	*Substage*	*Zone*
Lower Pliocene	Kalimnan	—	*Nonion victoriense Cush.* *Planulina kalimnensis* Parr
Upper Miocene	Mitchellian	—	*Anomalina* sp. 1
Middle Miocene	Balcombian	Bairnsdale	*Cibicides victoriensis* Chap., Parr and Coll. *Operculina victoriensis* Chap. and Parr
		Batesford	*Lepidocyclina* (*Trybliolepidina*) *gippslandica* Cresp.
		Longford	*Clavulinoides szaboi* (Hantk.) var. *victoriensis* Cush.
	Janjukian	—	*Cyclammina incisa* (Stache)
	Anglesean	—	—

Detailed study of bores and outcrops.—The largest section of the paper.

Paleoecology of faunal assemblages.—An interesting study of each stage and substage on modern lines. There appears to be a more or less gradual transition from the moderately deep, cool water of the Janjukian, through moderately shallow, warm to subtropical conditions in the Balcombian, to warm, littoral to sub-littoral and fairly sheltered conditions in Kalimnan time. Terrestrial conditions were predominant in post-Kalimnan time in Gippsland, though oscillation from terrestrial to marine conditions is shown in two bores.

Correlation with other occurrences in southeastern Australia.

Correlation beyond southeastern Australia.—It is pointed out in this section that the correlation of the Victorian Tertiaries with those of New Zealand suggested by H. J. Finlay and J. Marwick (1940)[3] is based on the subgeneric determination of the Victorian *Lepidocyclina* as *Nephrolepidina* instead of *Trybliolepidina*, and until more is known of the New Zealand Lepidocyclinae it would be unwise to attempt any correlation. The presence of the restricted genus *Lepidocyclina*, together with *Cycloclypeus victoriensis* Cresp., *Austrotrillina howchini* (Schl.), *Marginopora vertebralis* (Q. and G.), *Amphistegina* and *Operculina* enables correlations to be made with deposits in Western Australia, Papua, New Guinea, and the Netherlands East Indies.

Distribution of fossil species in Gippsland.—Certain foraminiferal assemblages characteristic of certain stages; actual restricted species few, though several have a limited range. Brachiopoda common only in certain localities. Mollusca characteristic of certain stages and areas. Majority of ostracoda long-ranging, being mainly species described from recent seas.

Summary.—Here brief reference is made to several structural elements detected during the stratigraphic work, such as the "Baragwanath Anticline." A considerable thickening of Miocene sediments is shown in the central part of the basin, 3,312 feet being recorded in the Holland's Landing Bore[4] at the west end of Lake Victoria. The upper middle Mio-

[3] *Ibid.*

[4] The deepest well in Gippsland; referred to in some detail in a review of E. S. Hills' *The Physiography of Victoria* in *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 5 (May, 1943). The ages of certain beds in this bore are revised in the paper here reviewed.

cene age of the *Lepidocyclina* horizon is based on the presence of the subgenus *Tryblio-lepidina*, the absence of *Nephrolepidina*, and the affinity of the species of *Cycloclypeus* with those of the Netherlands East Indies in the "f_2–f_3" stage. Paleontological evidence indicates that no marine Tertiary sediments older than Miocene (most probably middle Miocene) are present in Gippsland. The basement (where reached in bores) consists of Jurassic feldspathic mudstones in the central part of the district, and of Paleozoic granite and metamorphic rocks in the south part.

RECENT PUBLICATIONS

ALABAMA

*"A Foraminiferal Fauna of the Wilcox Eocene, Bashi Formation, Yellow Bluff, Alabama," by Joseph A. Cushman. *Amer. Jour. Sci.*, Vol. 42, No. 1 (New Haven, Connecticut, January, 1944), pp. 7–18; 2 pls.

CALIFORNIA

*"Bituminous Sands and Shales and Partly Depleted Subsurface Sands as Sources of Additional Oil in California," by G. B. Shea. *California Oil World*, Vol. 36, No. 23 (First issue, December, 1943), pp. 9–13.

*"New Mollusks from the Round Mountain Silt (Temblor) Miocene of California," by A. Myra Keen. *Trans. San Diego Soc. Nat. Hist.*, Vol. 10, No. 2 (San Diego, December 30, 1943), pp. 25–60, Pls. 3–4, Figs. 1–5.

COLOMBIA

*"Historia del desarrollo y geologia general de los campos petroleros de La Cira e Infantas," by M. M. Mulholland. *Inst. Colombiano de Petrol. E. T. 6*, P. 305 (Bogota, March, 1943). 4 pp. Describes briefly the geology of the La Cira and Infantas oil fields. In Spanish.

FLORIDA

*"Florida Looms as Area for Future Exploration," by Rivers Reaves. *Oil Weekly*, Vol. 112, No. 5 (Houston, January 3, 1944), pp. 8–11, 22; 3 figs.

"The Natural Features of Southern Florida." *Florida Geol. Survey Bull. 25* (Tallahassee, August-September, 1943). Price, $0.15 (for postage and handling).

"Stratigraphic and Paleontologic Studies of Wells in Florida, No. 3," by W. Storrs Cole. *Florida Geol. Survey* (soon to be published). A study of well cuttings from the St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1, and from the City of Quincy water well.

"Late Cenozoic Geology of Southern Florida with a Discussion of the Ground Water," by Gerald A. Parker and C. Wythe Cooke. *Ibid.*

GENERAL

*"Undiscovered Reserves Equal to Those Already Found Held Probable," by Wallace E. Pratt. *Oil and Gas Jour.* Vol. 42, No. 34 (Tulsa, December 30, 1943), pp. 78–80.

*"Determining Probability of Success of Secondary-Recovery Operations. Part 8, Surface Tension Effects of Secondary Recovery," by Paul D. Torrey. *Oil Weekly*, Vol. 112, No. 5 (Houston, January 3, 1944), pp. 17–22; 3 figs.

*"Relationships between Price, Exploration Activity and Petroleum Discovery Volume," by E. E. Rosaire. *Ibid.*, pp. 26–34, 6 figs., 2 tables.

*"The Species Concept in Petrology," by S. J. Shand. *Amer. Jour. Sci.*, Vol. 242, No. 1 (New Haven, Connecticut, January 1, 1944), pp. 45–52.

*"Transportation and Deposition of Heavy Minerals," by Gordon Rittenhouse. *Bull. Geol. Soc. America*, Vol. 54, No. 12 (New York, December 1, 1943), pp. 1725–80; 10 figs.

*"Lower and Middle Cambrian Stratigraphy in the Great Basin Area," by Harry E. Wheeler. *Ibid.*, pp. 1781–1822; 5 figs.

ILLINOIS

*"Early Ordovician Strata along Fox River in Northern Illinois," by H. B. Willman and J. Norman Payne. *Jour. Geol.*, Vol. 51, No. 8 (Chicago, November-December, 1943), pp. 531–41, 4 figs., 6 tables.

"Water Flooding of Oil Sands in Illinois," by Frederick Squires and Alfred H. Bell. *Illinois Geol. Survey R. I. 89* (Urbana, 1944). Price, 0.25.

NEW MEXICO

*"A Reconnaissance and Elevation Map of Southeastern New Mexico," by Walter B. Lang. *U. S. Geol. Survey* (1943). Sheet, 31×48 inches. Scale, 1 = 253,440, or 4 miles to the inch.

PERU

*"Contributions to the Paleontology of Northern Peru. Pt. VII, The Cretaceous of the Paita Region," by A. A. Olsson. *Bulletins of Amer. Paleontology*, Vol. 28, No. III (Paleontological Research Institution, Ithaca, New York, January 6, 1944). 147 pp., 17 pls., 3 text figs., sketch map.

WISCONSIN

*"The Sediments of Four Woodland Lakes, Vilas County, Wisconsin. Part I," by W. H. Twenhofel, V. E. McKelvey, S. A. Carter, and Henry Nelson. *Amer. Jour. Sci.*, Vol. 242, No. 1 (New Haven, Connecticut, January, 1944), pp. 19–44; 8 tables, 5 figs.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 13, No. 3 (December, 1943).

"Rapid Methods of Making Sedimentational Analyses of Arenaceous Sediments," by Willard D. Pye

"Use of Paleontology by the Oil Industry," by Henry V. Howe

"Paleogeography and Petroleum Exploration," by John Emery Adams

"Aid of Sedimentary Petrology to the Discovery of Oil," by Raymond Sidwell

"An Experimental Study of the Influence of Grain-Size on the Size of Oscillation Ripple Mark," by O. F. Evans and Roy L. Ingram

"Memorial to Professor Charles Schuchert, 1858–1942," by W. H. Twenhofel

**Journal of Paleontology* (Tulsa, Oklahoma), Volume 18, No. 1 (January, 1944).

"Cretaceous of the Mesabi Iron Range, Minnesota," by Harlan R. Bergquist.

"Upper Devonian Bryozoa from New Mexico," by Madeleine A. Fritz.

"*Parafavosites* and Similar Tabulate Corals," by R. S. Bassler.

"Catalogue and Revision of the Gastropod Subfamily Typhinae," by A. Myra Keen.

"The Genus *Aturia* in the Tertiary of Australia," by Curt Teichert.

"Two New Ammonoids from the Permian of Western Australia," by Curt Teichert.

"A Permian Shark from the Grand Canyon," by Lore R. David.

"Hystatoceratidae or Dipoloceratidae?" by Otto Haas.

"Impression of a Worm on the Test of a Cambrian Trilobite," by Rudolf Ruedemann and B. F. Howell.

"*Lamellinucula*, A New Subgenus of Nuculid Pelecypods," by Hubert G. Schenck.

"A New Coral from the Buda Limestone (Cenomanian) of Texas," by John W. Wells.

"Notes on Fresh-Water Mollusks of Idaho Formation at Hammett, Idaho," by Teng-Chien Yen.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 2 (FEBRUARY, 1944), PP. 283-294

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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(Continued on page 299)

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[1] From March, 1929, to March, 1932, the corresponding office was *first vice-president*.
[2] From March, 1929, to March, 1932, the corresponding office was *second vice-president in charge of finances*.
[3] From March, 1929, to March, 1932, the corresponding office was *third vice-president in charge of editorial work*.
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[5] Died, January 3, 1940.
[6] Died January 10, 1939.
[7] Died, July 9, 1943.
[8] Died, November 5, 1932.
[9] Died, January 29, 1940.
[10] Died, December 13, 1943.
[11] Died, July 5, 1940.
[12] Died, July 8, 1939.

JOINT ANNUAL MEETING, DALLAS, MARCH 21–23, 1944

A. RODGER DENISON[1]
Tulsa, Oklahoma

ANNOUNCEMENT

The 29th annual meeting of the American Association of Petroleum Geologists, the 14th annual meeting of the Society of Exploration Geophysicists, and the 18th annual meeting of the Society of Economic Paleontologists and Mineralogists will be held at Dallas, Texas, March 21, 22, and 23, 1944, at the invitation of the Dallas Petroleum Geologists. The Baker Hotel is headquarters.

SECOND WAR-TIME CONFERENCE

This meeting will be the second war-time joint conference of the three exploratory societies. This is a conference of essential technical men in a critical activity of war effort, that is, petroleum exploration. Recognizing the critical position of petroleum and its products in winning the war, they accept the responsibility of finding new supplies to replace the diminishing reserves. The program of this meeting is being organized to bring to the members, through special speakers, conferences, and discussions, new ideas and methods for improving exploration efficiency. There will be a re-examination of prospective areas in the United States and other parts of the world. The sessions are to be confined strictly to business and technical matters. There will be no banquet, dance, golf tournament, or field trips. Because of greatly restricted hotel space, there will be no possibility of accommodating wives.

The program will again be restricted to subjects of broad general interest and no papers of local interest will be placed on the oral program. Titles of papers, with abstracts, for inclusion in the printed program, are invited and should be submitted by February 15 to A.A.P.G. headquarters, Box 979, Tulsa 1, Oklahoma.

NOTICE OF MEETING TO RENEW ASSOCIATION CERTIFICATE OF INCORPORATION

TO THE MEMBERS OF THE A.A.P.G.—On Thursday, March 23, 1944, at 4:00 P.M., the annual business meeting of the Association will be held in the Ball Room on the Mezzanine of the Baker Hotel, Dallas. At this meeting the members will be asked to consider the renewal of the Certificate of Incorporation of the Association, which certificate expires under the statutes of the State of Colorado, on April 23, 1944.

OUTLINE OF PROGRAM

MARCH 21, TUESDAY	A.M.	Standing and special committees; research committee conferences S.E.G. business and technical sessions
	P.M.	Annual business meeting; research conferences S.E.G. sessions
	NIGHT	Research symposium
MARCH 22, WEDNESDAY	A.M.	Reviews of 1943; presidential addresses
	P.M.	Special speakers
	NIGHT	Special guest speaker
MARCH 23, THURSDAY		Re-examination of prospective regions; world reserves; foreign regions S.E.P.M. business and technical sessions Symposium on foreign regions

EXHIBITS

The usual exhibit of scientific equipment and exploratory methods will be arranged insofar as practical. Also, space will be available for map displays of educational institutions, geological societies, and State surveys. Inquiries should be directed to the A.A.P.G., Box 979, Tulsa 1, Oklahoma.

[1] President of the Association.

TRANSPORTATION

If you do not have your own means of transportation, and plan to travel by Pullman: *first*, be certain that you can attend the meeting; *second*, make your Pullman reservations, both going and return, well in *advance; third*, cancel reservations immediately if you find you can not use them. The meeting closes a day earlier in the week, this year, in order to avoid week-end travel congestion.

HOTELS

Hotel rooms are available only in limited number. You should make your own reservation *now*, direct with the hotel of your choice; request the hotel for confirmation; do not go to the meeting on the mere chance or hope of getting a hotel room; *go only if you hold hotel confirmation of reservation;* if you find you can not attend, cancel immediately any reservation you have made. Hotel rooms and service are already seriously taxed. It will be necessary in many cases for members to double up in room occupancy. Many former single rooms will contain two beds. Select a friend to share a double room with you.

The chairman of the hotel and housing committee is Eugene McDermott, Geophysical Service, Inc., 1311 Republic Bank Building, Dallas, Texas. If you are unable to find hotel or other housing accommodations the committee will assist you in every way possible.

Hotel	*Rooms*	*Single*	*Double*
Baker Hotel (Headquarters)	700	$2.50 up	$4.00 up
Adolphus Hotel (Opp. Headquarters)	825	2.50 up	4.00 up
White Plaza (4 Blocks from Hdqs.)	300	2.00–4.00	3.00–6.00
Jefferson Hotel (6 Blocks from Hdqs.)	450	2.00 up	2.50 up
Cliff Towers Zangs and Colorado Sts.	450	2.00 up	3.00 up
Mayfair Hotel 723 N. St. Paul	150	2.50 up	2.50 up
Melrose Hotel 3015 Oak Lawn Ave.	325	3.00 up	4.00 up
Stoneleigh Hotel Apt. 2927 Maple Ave.	400	3.00–7.50	4.50–10.00
Maple Terrace 3001 Maple Ave.	400	3.00–7.50	4.50–10.00

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A. RODGER DENISON[1]
Tulsa, Oklahoma

Below is listed a tabulation by states of the number of contributors and the amounts contributed; there is also a tabulation of those from foreign countries. The contributors now total 746; this is 19 per cent of our membership (as shown in March, 1943, *Bulletin*). The percentage of participation by our members in those states having more than 100 members is as follows.

State	*Percentage*	*State*	*Percentage*
California	24.6	Louisiana	13.4
Illinois	31.7	Oklahoma	32.1
Kansas	14.2	Texas	21.9

CONTRIBUTION (TO JANUARY 1, 1944)

State	*Contributors*	*Amount*	*State*	*Contributors*	*Amount*
Alabama	4	$ 5.00	Missouri	5	35.00
Arkansas	2	3.50	Montana	6	12.50
California	88	773.50	New Jersey	4	20.00
Colorado	9	36.00	New Mexico	8	17.00
Connecticut	2	15.00	New York	27	282.50
District of Columbia	25	206.00	North Carolina	1	2.50
Florida	1	5.00	Ohio	6	126.50
Georgia	1	1.00	Oklahoma	135	1,099.00
Illinois	42	388.50	Pennsylvania	8	41.00
Indiana	10	35.00	South Dakota	1	1.25
Kansas	24	104.00	Texas	210	1,550.50
Kentucky	2	5.00	Utah	2	7.50
Louisiana	31	113.50	Virginia	5	8.50
Maryland	2	3.50	Washington	2	7.50
Massachusetts	5	62.50	West Virginia	6	17.00
Michigan	10	32.50	Wisconsin	1	1.00
Minnesota	3	10.00	Wyoming	1	5.00
Mississippi	18	48.50	Total	707	$5,082.25

Foreign Countries	*Contributors*	*Amount*	*Foreign Countries*	*Contributors*	*Amount*
Argentina	3	15.00	Egypt	3	22.50
Canada	6	35.00	Hawaii	1	2.50
Chile	1	10.00	Mexico	4	37.50
Colombia	5	31.00	Peru	1	5.00
Costa Rica	1	2.50	Venezuela	8	50.00
Cuba	1	5.00	Total	39	$ 241.00
Dominican Republic	2	10.00	Grand total	746	$5,323.25
Ecuador	3	15.00			

[1] Chairman, medal award committee.

CONTRIBUTIONS BY AMOUNTS

12	$100.00	$1,200.00	2	$ 4.00	$ 8.00
6	50.00	300.00	1	4.50	4.50
1	30.00	30.00	1	3.50	3.50
27	25.00	675.00	36	3.00	108.00
4	20.00	80.00	241	2.50	602.50
6	15.00	90.00	50	2.00	100.00
106	10.00	1,060.00	2	1.50	3.00
1	7.50	7.50	1	1.25	1.25
1	6.00	6.00	49	1.00	49.00
199	5.00	995.00			
			Total		$5,323.25

STUDENTS OF GEOLOGY MAY BE DEFERRED

A. RODGER DENISON[1]
Tulsa, Oklahoma

Through the kindness of Homer L. Dodge, director of the Office of Scientific Personnel of the National Research Council, we are presenting herewith early information on the new Selective Service regulations which for the first time lists students of geology and geophysics as qualified for deferment under certain conditions. The inclusion of these two classes of students has been brought about by the combined efforts of the various groups in the geological profession in pointing out to Selective Service and others the need for the training of geologists and geophysicists. W. W. Rubey, who is chairman of the Division of Geology and Geography of the National Research Council, organized a committee for the study of manpower problems in geology. It is upon his suggestion that Dr. Dodge has compiled the information given below.

NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue
Washington, D. C.

OFFICE OF SCIENTIFIC PERSONNEL

INFORMATION BULLETIN NO. 7 (Special) January 11, 1944

SUBJECT: *Occupational Deferments for Geologists, Geophysicists and Students of Geology and Geophysics in the Lower Age Group*

This special bulletin has been issued at the request of Mr. W. W. Rubey, Chairman of the Division of Geology and Geography of the National Research Council and member of the NRC Committee in charge of the work of the Office of Scientific Personnel. It has been prepared especially for distribution to departments of geology where there are major students in geology for whom occupational deferment should be requested. This office has been active in advising Selective Service and employers with respect to deferments of scientific and technical personnel, and it opened the way for the inclusion of geology in the small list of fields in which occupational deferment may be secured for students of ages 18 through 21. For this reason we are glad to prepare and distribute this special bulletin.

Yesterday, on January 10, there was issued by Selective Service Headquarters an amended edition of Activity and Occupation Bulletin No. 33-6 (effective February 15) which deals with Student Deferment. Along with this, and accompanied by Transmittal Memo No. 96, were issued amended editions of Local Board Memoranda Nos. 115 and 115-B (effective February 1) which deal with Occupational Classifications. This material covers 56 pages and it is recommended that copies be secured from National Selective Service Headquarters, 21st and C Streets, N. W., Washington 25, D. C., or from a local board.

Geologist and geophysicist have been, and are, listed among the Professional and Scientific Occupations in the Part II of LBM 115. Accordingly, after February 1, a registrant who is a geologist or geophysicist in the 18 through 21 age group is eligible for occupational deferment *only* if:

[1] President of the Association.

(a) there is filed with the local board a Form 42-A Special already endorsed by the State Director of the state where the registrant is employed, specifically excepting the registrant from the general restrictions of this memorandum; or
(b) the local board determines that the registrant is either "Personnel of the Merchant Marine . . ." or a student qualifying under AOB 33-6.

Requests for deferments under (a) above are made by submitting Form 42-A Special in triplicate to the State Director concerned and under (b) above by submitting Form 42 Special in triplicate to the National Roster of Scientific and Specialized Personnel.

Although "geologist" has been listed as one of the "Professional and Scientific Occupations" in LBM 115, *students of geology* have not been listed among those who could be considered for occupational deferment. In other words "geologists" have never appeared as one of the twenty-odd scientific and specialized fields mentioned in the various editions of AOB 33-6. In the amended edition of AOB 33-6, becoming effective on February 15, the number of fields is greatly reduced, but it has been possible to secure the inclusion of geology. The new AOB 33-6 provides for the occupational deferment of undergraduate students who will graduate after July 1, 1944, in the fields of chemistry, engineering, geology, geophysics, and physics.

An undergraduate student in any of these fields will be considered for occupational deferment if he is a full-time student in good standing in a recognized college or university and if it is certified as follows:

(a) "By the institution that he is an undergraduate student majoring in one of the scientific and specialized fields listed in this paragraph and that he gives promise of the successful completion of his course of study;
(b) "By the institution that if he continues his progress, he will graduate within 24 months from the date of certification; and
(c) "By the National Roster of Scientific and Specialized Personnel of the War Manpower Commission that the certification of the institution as to his course of study and competence and as to his prospective date of completion is correct to the best of its knowledge and belief and that his deferment, if granted, will be within the national quota for such students."

A national quota of 10,000 has been established for students who should be occupationally deferred at any one time by reason of pursuing courses of study in chemistry, engineering, geology, geophysics, and physics. Students deferred to graduate on or before July 1, 1944 (as provided in Sub-Part B, which does not include geology) and students deferred for reasons other than pursuing a course of study will not be counted against this quota.

The inconsistency of having geologists graduating *after* July 1 deferable but those graduating *before* July 1 non-deferable has been pointed out to Selective Service, and the logical inconsistency will be remedied in the administrative procedure which will operate to defer students of geology graduating before July 1 as if this field were listed.

The institution in which the registrant is a student will prepare requests for occupational deferment of students as follows:

(a) "For a student who has reached his eighteenth birthday but has not reached his twenty-second birthday, in duplicate on DSS Form 42 Special; and
(b) "For a student who is 22 years of age or older, on DSS Form 42."

These forms will be forwarded by the institutions to the National Roster of Scientific and Specialized Personnel, which will certify to requests for occupational deferment of a registrant in geology. The National Roster will, if such is the case, certify on the request that the statements of the institution as to the course of study and competence and prospective date of completion of the registrant are correct to the best of its knowledge and belief and that the registrant's deferment, if granted, will not exceed the quota established for such students. The Roster will return the request for occupational deferment of students, whether certified to or not, to the institution which prepared the request so that it may be filed with the local board.

What Departments of Geology Should Do

The National Roster has already consulted with presidents of colleges and universities with regard to the problem of further occupational deferment of students and has requested certain information. On the basis of the information collected, the National Roster will prepare plans for institutional quotas, etc., and will communicate with departments of chemistry, engineering, geology, geophysics, and physics through the president of the institution. The head of the department of geology should at once accumulate all pertinent data with regard to its major students, should prepare to assist the president in the furnishing of all information needed by the Roster, and be ready to file requests for occupational deferment on the proper forms in due time, as explained above. He should make certain that he sees all communications from the Roster immediately on receipt at the president's office.

Since the national and institutional quotas will be small in each field, it should be noted that "students deferred for reasons other than pursuing a course of study will not be counted against this quota." That is, the 10,000 quota does not include registrants classified 4-F. A department will do well to determine which of its students are likely to be 4-F's and not ask for their deferment. Pre-induction physical examinations should be arranged wherever possible.

Teachers and Graduate Assistants

The new AOB 33-6 makes no provision for graduate students, but attention should be given to the footnote on page 9 of LBM 115, applying to the list of Professional and Scientific Occupation, in which list "geologist" appears. The note reads:

"The titles appearing in this Part of the list of Critical Occupations with definitions shall be considered as also including persons engaged in full-time teaching of these professions. A person may be considered as engaged in *full-time teaching if he devotes not less than 15 hours per week in contact with students* in actual classroom or laboratory instruction. These titles are also intended to include persons who are engaged in full-time inspecting duties which require the utilization of the knowledge of the critical occupations listed in Part II."

Homer L. Dodge, Director
Office of Scientific Personnel

NATIONAL ROSTER OF SCIENTIFIC AND SPECIALIZED PERSONNEL DESCRIPTION OF PROFESSION OF GEOLOGY

A. RODGER DENISON[1]
Tulsa, Oklahoma

The National Roster of Scientific and Specialized Personnel has been engaged for some time in compiling the descriptions of various scientific and technical professions. Among these is the profession of geology. Prior to final adoption of the description given below a copy of the material was forwarded to the Association asking for comments and criticisms. This material was examined by the executive committee and others and suggestions were forwarded to Leonard Carmichael, director. The material incorporates a large number of the suggestions made by the Association.

This description is to be furnished to all local offices of the United States Employment Service. This is being distributed, according to Dr. Carmichael, in connection with "the training program which will get under way in the very near future and which should result in more effective services to professional personnel." Being on file in the offices of the U. S. Employment Service, this will also be available for use by local Selective Service Boards when they have need to determine whether a registrant qualifies under the profession of geology.

Description of the Profession of:

GEOLOGY

0-39.45 GEOLOGIST
0-39.46 PALEONTOLOGIST

Occupational Summary

Geology is the science of the earth's constitution, structure and history as disclosed by the sequence of formations and deformations of rock layers and by the fossil or mineral content of such layers. The field comprises three major subject-matter subdivisions: A. economic, B. physical, and C. historical geology. From an occupational standpoint the field is generally subdivided into six branches:

1. economic geology
2. mineralogy
3. petrology
4. surficial geology
5. stratigraphy
6. paleontology

A. *Economic geology* relates to the exploration, exploitation and study of useful mineral deposits (oil, gas, metal ores, water, etc.); also the study of dam sites, foundations and abutments.

[1] President of the Association.

B. *Physical or dynamical geology* is concerned with the formation, arrangement and aggregation of rocks and with the agencies and processes of geological change, particularly the effects of great pressures and temperatures. It thus includes the specialties of mineralogy, petrology, structural and surficial geology.

C. *Historical geology* is the study of the successive development of rock formations and the fossil remains of animal and vegetable life and their relation to rock formations. (1) Stratigraphy is the study of the chronological succession of rocks from the earliest igneous to the most recent formations. The rocks are identified and classified by their position, composition and characteristic fossils. (2) Paleontology is concerned with the identification and classification of prehistoric forms of plant and animal life as revealed by fossil remains. This field is an important basis of stratigraphy. (3) The related fields of geodesy, seismology, oceanography, hydrology, tectonophysics and terrestrial magnetism are described under "Geophysics and Related Fields," or separately.

Major Branches

I. *Economic geology*, relating to the study and report on the occurrence, availability, quantity and value of minerals by investigating, collecting specimens, and mapping in the field the extent, thickness and slope of surrounding rocks, is subdivided according to type of deposit. The most important field, *petroleum geology*, is often treated as a separate branch of geology. Economic geology is subdivided into specialties according to type of mineral deposits and uses involved. The major specialties are listed below in order of their importance.

a. Oil and natural gas (petroleum geology)
b. Metallic minerals and ores
c. Non-metallic minerals
d. Coal
e. Refractory and ceramic materials
f. Ground water
g. Industrial and structural stone

II. *Mineralogy*—relates to the study of minerals, gems and precious stones, including microscopic examination, physical and chemical tests, x-ray, and crystal structure, for purposes of identification, classification and determination of mode of origin. This science also deals with the occurrence and uses of minerals, and with the special subject of *meteorites*—the fragments of other planets fallen upon the earth.

III. *Petrology* is the study of the origin, structure, composition, classification of the rocks forming the earth's crust. The descriptive phase is known as *petrography*. Specialties in this field are igneous, metamorphic and sedimentary petrology. *Geochemistry* relates to the chemical changes which alter the composition of rocks.

IV. *Surficial geology* relates to the study of rocks on the earth's surface.

a. *Geomorphology* deals with the origin of topographic features and those forces, as erosion, which modify the earth's surface.
b. *Glacial geology* deals with the origin, movement and effects of glaciers.
c. *Submarine geology* and topography is concerned with ocean bottom conditions.

V. *Stratigraphy* is the study of the successive layers of rocks and is specialized according to major geological periods. It includes the field of sedimentation, or the processes of formation of layers of clay, rock, etc. through the slow deposition of rock or soil grains and fragments.

VI. *Paleontology* relates to the classification and description of prehistoric remains of plant and animal life. It is a field which is fundamental to nearly all branches of geology.

Functional Specializations

Geologists specialize in any one or more of the following functions in addition to any of the major branches or specialties previously described.

1. Research
2. Museum work
3. Consulting
4. Teaching
5. Field work including exploration
6. Administration

Educational Qualifications

a. The minimum of a bachelor's degree in geology, or frequently in some related or subordinate science, as mineralogy or paleontology.

b. In those few cases in which the formal professional training is more limited, there must be evidence of many years of progressive and varied professional experience which can be considered as the equivalent of the formal education which is lacking.

Professional Affiliations

Full membership in a national or local professional organization is generally limited to individuals who have acceptable professional qualifications. Lack of such membership, however, should not be construed as indicative of non-professional status.

Related Professional Fields

Geology is closely allied to and is often classified together with the geophysical and related specialties listed in the summary. There is also an overlapping with the prospecting phases of mining and petroleum engineering and with mineral technology.

Industry

Geologists are employed principally in the following industries:

1. coal, metal and mineral mining
2. petroleum and natural gas production
3. colleges and universities
4. government—Federal and state
5. non-profit research agencies, including museums

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 2 (FEBRUARY, 1944), PP. 295-300

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

W. H. WHITE, formerly in the Division of Geology, Nashville, Tennessee, is employed by The California Company, New Orleans, Louisiana.

VERNON E. AUTRY has resigned his position with Fain and McGaha to work independently at Wichita Falls, Texas.

LANHAM TODD CLARK is junior seismologist with the Superior Oil Company, Seminole, Texas.

NOYES B. LIVINGSTON is a geologist for the Bolivian Government. He may be addressed at Casilla No. 7, Y. P. F. Bolivianos, Oran, F.C.C.N.A. (Salta) Argentina.

FRANK REEVES is in the Foreign Division of the Petroleum Administration for War, Washington, D. C.

JOHN ERIC BUCHER has left the Ohio Oil Company and is employed by the Standard Oil Company of Texas, Midland, Texas.

T. C. HIESTAND, of the Cities Service Oil Company, Bartlesville, Oklahoma, is at Casper, Wyoming, for a few months.

IRA A. BRINKERHOFF, formerly with the Standard Oil Company of Indiana, at Chicago, is connected with the Texas Gulf Producing Company, Houston, Texas.

ROBERT C. SENNING resigned from the Republic Natural Gas Company last December. He is employed by the Western Company at Midland, Texas.

C. TAYLOR COLE, of Midland, Texas, has resigned his position with the Lario Oil and Gas Company and is now engaged in consulting work.

C. H. ACHESON has been transferred from the Tropical Oil Company in Colombia, to the Imperial Oil Producing Company at Calgary, Alberta.

KENNETH S. FERGUSON, for the past 7 years district geologist for the Shell Oil Company, Inc., at Midland, Texas, in charge of West Texas and southeastern New Mexico, has resigned and moved to La Jolla, California.

GEORGE OTIS SMITH, honorary member of the Association and for many years director of the United States Geological Survey, died at Augusta, Maine, January 10, at the age of 72 years.

THOMAS S. COX, who has been engaged in independent work at Evansville, Indiana, for the past 18 months, recently joined the Husky Refining Company as geologist and magnetometer operator, at Cody, Wyoming.

Lieutenant ROBERT W. EVERETT, JR., formerly employed in the geophysical department of the Arkansas Fuel Oil Company, was commissioned as a communications officer, Army Air Forces, from the Technical School, Yale University on Jan. 6, 1944, and is now stationed in Chicago.

The West Texas Geological Society, Midland, Texas, has elected the following officers for 1944: president, ROBERT I. DICKEY, district geologist for the Forest Development

Corporation; vice-president, GEORGE R. GIBSON, district geologist for the Richfield Oil Corporation; and secretary-treasurer, JANE FERRELL, geologist for the Magnolia Petroleum Company.

The Ardmore Geological Society, Ardmore, Oklahoma, has elected the following officers for the current year: president, JOHN MARSHALL, 418 Simpson Building; vice-president, FRANK NEIGHBOR, Sinclair-Prairie Oil Company; secretary-treasurer, S. L. ROSE, 618 Simpson Building.

P. A. WALLACE, geologist with the Amerada Petroleum Corporation at Shawnee, has resigned to join Ray Stephens, Inc., and Stephens Brothers, Oklahoma City, Oklahoma.

WALTER L. GOLDSTON has been elected chairman of the board of directors of the University State Bank, Houston, Texas.

FREDERICK G. CLAPP is back in the United States after an engagement as consulting specialist on petroleum for the Republic of Turkey. His business address is 50 Church Street, New York City.

CHARLES BREWER, JR., president of the Appalachian Geological Society, Charleston, West Virginia, died on January 2.

FREDERIC H. LAHEE, chief geologist of the Sun Oil Company, Dallas, Texas, is the official representative of the American Association of Petroleum Geologists in connection with the forthcoming meeting of the Petroleum Industries War Council and the Petroleum Administration for War, in connection with the work which is to be done on the definition of wildcat and extension wells. The appointment is by president A. R. Denison of the A.A.P.G.

At the monthly meeting, the South Louisiana Geological Society, Lake Charles, Louisiana, has elected the following officers for the ensuing year: president, C. B. ROACH, Shell Oil Company, Inc.; vice-president, P. S. SCHOENECK, Atlantic Refining Company; secretary, BEN F. MORGAN, Stanolind Oil and Gas Company; treasurer, R. N. WATSON, Atlantic Refining Company. Dinner and business meetings are held on the second Tuesday of each month at 7:00 P.M., at the Majestic Hotel. Visiting geologists are welcome.

The Fort Worth Geological Society has completed another successful year. Among the many and varied activities, the A.A.P.G. convention, April 7, 8, 9, was the outstanding event. As host for the meeting, the Society, through its committees, used the capabilities of every one of its members. Thirty-four regular meetings were held during the year, with a special speaker and his topic as the main feature for thirty of these meetings. Eight outstanding men in their respective fields, sponsored by the A.A.P.G. distinguished lecture program, were heard: L. B. KELLUM, professor of geology, University of Michigan; ERNST CLOOS, professor of geology, The Johns Hopkins University; JOHN L. RICH, head of department of geology, University of Chincinnati; PAUL D. KRYNINE, professor of geology, Pennsylvania State College; W. TAYLOR THOM, JR., professor of geology, Princeton University; CLAUDE E. ZOBELL, Scripps Institution of Oceanography; Richard J. RUSSELL, professor of Geology, Louisiana State University; and EZEQUIEL ORDONEZ, Mexican Scientific Commission of Paracutin. Many other outstanding guest speakers appeared before the Society: C. W. TOMLINSON, Ardmore, Oklahoma; RALPH W. IMLAY, U. S. National Museum; and CHARLES B. CARPENTER and ALTON B. COOK, U. S. Bureau of Mines. Thirteen of the thirty talks were of a geological nature; seven programs consisted of talks along the lines of petroleum engineering, production methods, and related subjects, while the remaining ten programs consisted of talks, pictures, or demonstrations on a wide variety of subjects. Joint meetings were held

with the Petroleum Engineers Club of Fort Worth from September 15 to the close of the year. The following officers were elected on January 13, for 1944: JOSEPH H. MARKLEY, JR., The Texas Company, president; J. WILLARD GILL, Pure Oil Company, vice-president; and SPENCER NORMAND, Independent Exploration Company, secretary-treasurer. Visiting geologists and friends are welcome at the Society's meetings.

O. V. WYSZNSKI, formerly Rio de Janeiro, Brazil, is at 2118 Las Palmas Avenue, Hollywood, California.

GEORGE DICKINSON has left the Shell Company, Inc., at Houston, and may be addressed in care of the Caribbean Petroleum Company, Maracaibo, Venezuela.

H. C. MCCARVER is with the Seaboard Oil Company, Continental Building, Dallas, Texas.

RALPH H. HOWE is with a Petty Seismic Party, Caribbean Petroleum Company, Maracaibo, Venezuela.

DONALD K. MACKAY is with the Foreign Economic Administration, Petroleum Division, Washington, D. C.

F. E. MARSHALL is chief geologist for the Snowden and McSweeney Company, Sinclair Building, Fort Worth, Texas.

MARCUS A. HANNA, of the Gulf Oil Corporation, Houston, Texas, talked on "The Stratigraphy and Structure of Salt Domes," at the regular meeting of the Shreveport Geological Society, January 24.

At the December meeting of the Appalachian Geological Society, the following officers were elected for 1944: president, DOUGLAS ROGERS, JR., South Penn Natural Gas Company, Parkersburg, West Virginia; vice-president, VELEAIR C. SMITH, of the Veleair C. Smith Management, Kanawha Valley Bank Building, Charleston, West Virginia; secretary-treasurer, A. E. PETTIT, Hamilton Gas Corporation, Box 2387, Charleston; editor, H. J. SIMMONS, JR., Godfrey L. Cabot, Inc., Charleston.

OTTO E. BROWN of the Gulf Oil Corporation, Mattoon, Illinois, was elected vice president of the Illinois Geological Society on January 10, replacing CLARK T. SNIDER of the Lario Oil and Gas Company, Mt. Vernon, Illinois, who has been transferred to Wichita, Kansas.

JAMES M. DORREEN, Lieutenant in the Royal New Zealand Expeditionary Force, was captured by the Italians at El Alamein in North Africa in August, 1942, during Rommel's final sweep toward Alexandria. He was sent to a prisoner-of-war camp in Italy. In November, 1942, he wrote that he was studying Spanish and German and lecturing in geology at a university in the P.O.W. Camp. On October 26, 1943, Dorreen wrote from a Kriegsgefangenenlager (prisoner's camp) in Germany, whence he was shipped after the Allies began their invasion of Italy.

DISTINGUISHED LECTURES

SAM H. KNIGHT, head of the department of geology, University of Wyoming, made a lecture tour during January under the auspices of the distinguished lecture committee of the A.A.P.G., discussing the geology of the Rocky Mountains in three different lectures illustrated with his very illuminating block diagrams in colored chalk.

He gave his talk on "Physical Evolution of the Rocky Mountains" before the following societies.

January 4 Oklahoma City Geological Society at Oklahoma City
5 Ardmore Geological Society at Ardmore
7 Tulsa Geological Society at Bartlesville
10 Illinois Geological Society at Mattoon
11 Mississippi Geological Society at Jackson
12 Shreveport Geological Society at Shreveport
13 East Texas Geological Society at Tyler
14 New Orleans Geological Society at New Orleans
17 Houston Geological Society at Houston
18 South Texas Geological Society at San Antonio
21 Pacific Section, A.A.P.G. at Los Angeles
22 San Joaquin Geological Society at Bakersfield
27 Texas Technological College at Lubbock

His lecture on "The Stratigraphy and Lithogenesis of the Late Paleozoic Rocks of Southeastern Wyoming" was heard by the following societies.

January 3 Kansas Geological Society at Wichita
26 West Texas Geological Society at Midland
28 Panhandle Geological Society at Amarillo

The lecture entitled "The Evolution of a Rocky Mountain Tertiary Basin" was presented by Dr. Knight before the Tulsa Geological Society at Tulsa, January 6.

JOHN L. FERGUSON, *chairman*

H. C. PETERSEN is superintendent of land and exploration for the Freeport Sulphur Company. He is president of the New Orleans Geological Society.

ARTHUR J. TIEJE, professor of geology at the University of Southern California, died at Pasadena, January 25, following an operation.

F. JULIUS FOHS, president of the Fohs Oil Company, Mellie Esperson Building, Houston, Texas, whose New York address has long been 183 Madison Avenue, has moved his office to Room 1106, 11 East 44th Street, New York 17, N. Y.

CHARLES W. FOWLER, JR., has been elected first vice-president in charge of operations and a member of the board of directors, of the Pantepec Oil Company of Venezuela, Caracas. The company is developing and producing from El Roble field in Anzoategui and the Mulata field in Monagas.

CAPTAIN C. Z. LEONARD, C.E., has returned to the United States after being in Greenland 15 months. His address is U. S. Engineers Field Office, Box 660, Fort Pierce, Florida.

J. J. DOZY, formerly with the Shell of Ecuador, may be addressed in care of N. V. de Bataafsche Petroleum Mij., Lensbury Club, Teddington, Middlesex, England.

T. E. WALL is engaged in consulting work, with offices at 1015½ Broadway, Mt. Vernon, Illinois. He was formerly geologist for the National Petroleum Company and the Southwestern Royalty Company.

ALEX W. MCCOY, vice-president of the Deep Rock Oil Corporation, discussed stratigraphic geology in Italy at the luncheon meeting of the Tulsa Geological Society, January 25.

ADDITIONAL MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

(continued from page 283)

FOR ACTIVE MEMBERSHIP

Albert J. Barthelmes, Tulsa, Okla.
G. H. Westby, J. L. Gartner, S. W. Wilcox
Samuel L. Clark, Jr., Shreveport, La.
G. D. Thomas, L. M. Crow, Everett Eaves
Louis Cowles Conant, University, Miss.
Watson H. Monroe, Henry N. Toler, Frederic F. Mellen
Michael Bertram Bray Crockford, Calgary, Alta., Canada
J. M. Kirby, J. O. G. Sanderson, W. C. Howells
Kenneth Arnold Gorton, Thompson, Utah
Jed B. Maebius, Harry A. Aurand, A. J. Eardley
Homer H. Luttrell, Effingham, Ill.
C. E. Hamilton, Ray E. Claiborne, Richard W. Camp
Ralph W. Melhorn, Owosso, Mich.
Kurt H. de Cousser, Richard A. Smith, Rex P. Grant
Guilford Clarence Pfeffer, Whittier, Calif.
Ashly S. Holston, R. E. Lindsay, Joseph Jensen

FOR ASSOCIATE MEMBERSHIP

Wesley Edward Davis, Shelby, Mont.
Paul T. Walton, Charles E. Erdmann, John E. Blixt
Oscar Alvin Erdman, Ottawa, Ont., Canada
Conrad O. Hage, George S. Hume, Hugh H. Beach
Otto Hackel, Los Altos, Calif.
Donald D. Hughes, Eliot Blackwelder, Hubert G. Schenck
Harry Hathaway Hurd, South Gate, Calif.
E. H. Vallat, E. K. Soper, R. M. Barnes
Clyone Lynn Jacobsen, Norman, Okla.
Malcolm C. Oakes, Robert H. Dott, V. E. Monnett
Kenneth Phelps McLaughlin, San Antonio, Tex.
A. L. Selig, Gentry Kidd, H. E. Menger
Wilbur Alvin Nowotny, Houston, Tex.
W. B. Neill, Albert D. Ellis, Jr., Hal P. Bybee
Richard Charles Oburn, Wichita, Kan.
Lee H. Cornell, W. C. Imbt, Walter A. Ver Wiebe
Wallace William Rangeler, Beaumont, Tex.
C. B. Claypool, A. P. Allison, R. W. Pack
Raymond Siever, Urbana, Ill.
H. R. Wanless, Alfred H. Bell, L. E. Workman
George Douglas Springer, Calgary, Alta., Canada
J. M. Kirby, John Galloway, G. M. Furnival

FOR TRANSFER TO ACTIVE MEMBERSHIP

Carl T. Anderson, Dallas, Tex.
Gayle Scott, T. K. Knox, William J. Hilseweck
Rizer Everett, Wichita, Kan.
J. Peter Smith, Chris R. Sullivan, Wilford L. Cline
Frank Herring, Wichita, Kan.
E. R. Elledge, E. A. Koester, W. C. Imbt
Elizabeth Earl Stephenson, Houston, Tex.
Ira A. Brinkerhoff, Ray C. Lewis, Shirley L. Mason

F. H. McGUIGAN, geologist for the Lion Oil Refining Company, is in charge of the company's new West Texas-New Mexico district geological and land office at Midland, Texas. J. E. GAFFNEY is his assistant geologist.

DON B. GOULD, professor of geology at Colorado College, Colorado Springs, gave an illustrated talk on "The Geologic History of the Pikes Peak Region," before the Rocky Mountain Association of Petroleum Geologists, at Denver, Colorado, February 7.

GEORGE S. HUME, geologist for the Oil Controller of Canada, Ottawa, Ontario, spoke before the Tulsa Geological Society, February 7. He has been engaged in the study of western Canada for the Geological Survey of Canada for more than 20 years and is the author of many reports on that region.

HARRY L. BALDWIN, of the Phillips Petroleum Company, Bartlesville, Oklahoma, discussed "The Oil Industry of Argentina," at the regular meeting of the Tulsa Geological Society, January 17.

F. JULIUS FOHS, president of the Fohs Oil Company, Houston, Texas, talked on "Some Notes on the Geology and Resources of the Middle East," before the Shreveport Geological Society, February 7.

The 160th meeting of the American Institute of Mining and Metallurgical Engineers is being held in New York City, February 20–24. The Waldorf-Astoria Hotel is the headquarters. The Society of Economic Geologists holds concurrent meetings. The annual review number of A.I.M.E. *Mining and Metallurgy* (February, 1944) contains several articles on the petroleum industry:

"Foreword," by C. A. Warner,
"Production," by W. P. Haynes,
"Production Geology," by F. B. Plummer,
"Production Engineering," by L. E. Porter,
"Economics," by Norman D. Fitzgerald,
"Engineering Research," by Everett G. Trostel,
"Refinery Engineering," by Walter Miller,
"Geophysics," by L. W. Blau,
"Education," by Harry H. Power,

and a special article on "Geophysics," by C. A. Heiland.

CARLETON D. SPEED, JR., formerly chief of the Section of Exploration, Division of Reserves, Petroleum Administration for War, Washington, D. C., continues in the same capacity since the functions of the Reserves and Production Divisions have been consolidated under the Production Division. His home address remains Apartment 136, Park Central Hotel, 1900 "F" Street, N. W., Washington 6, D. C.

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The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Bldg.

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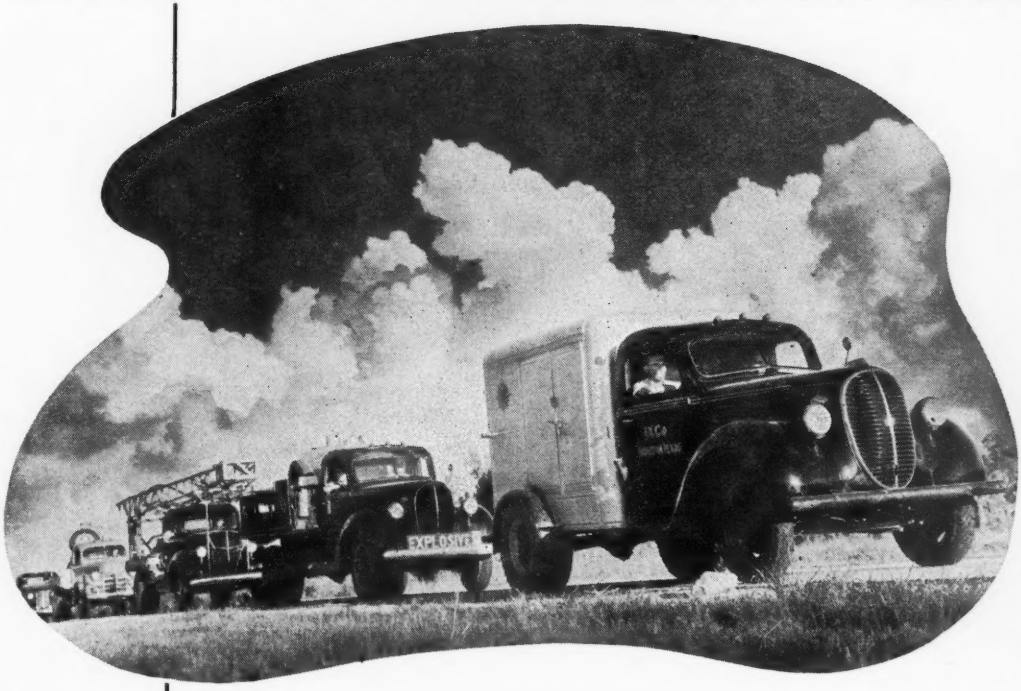

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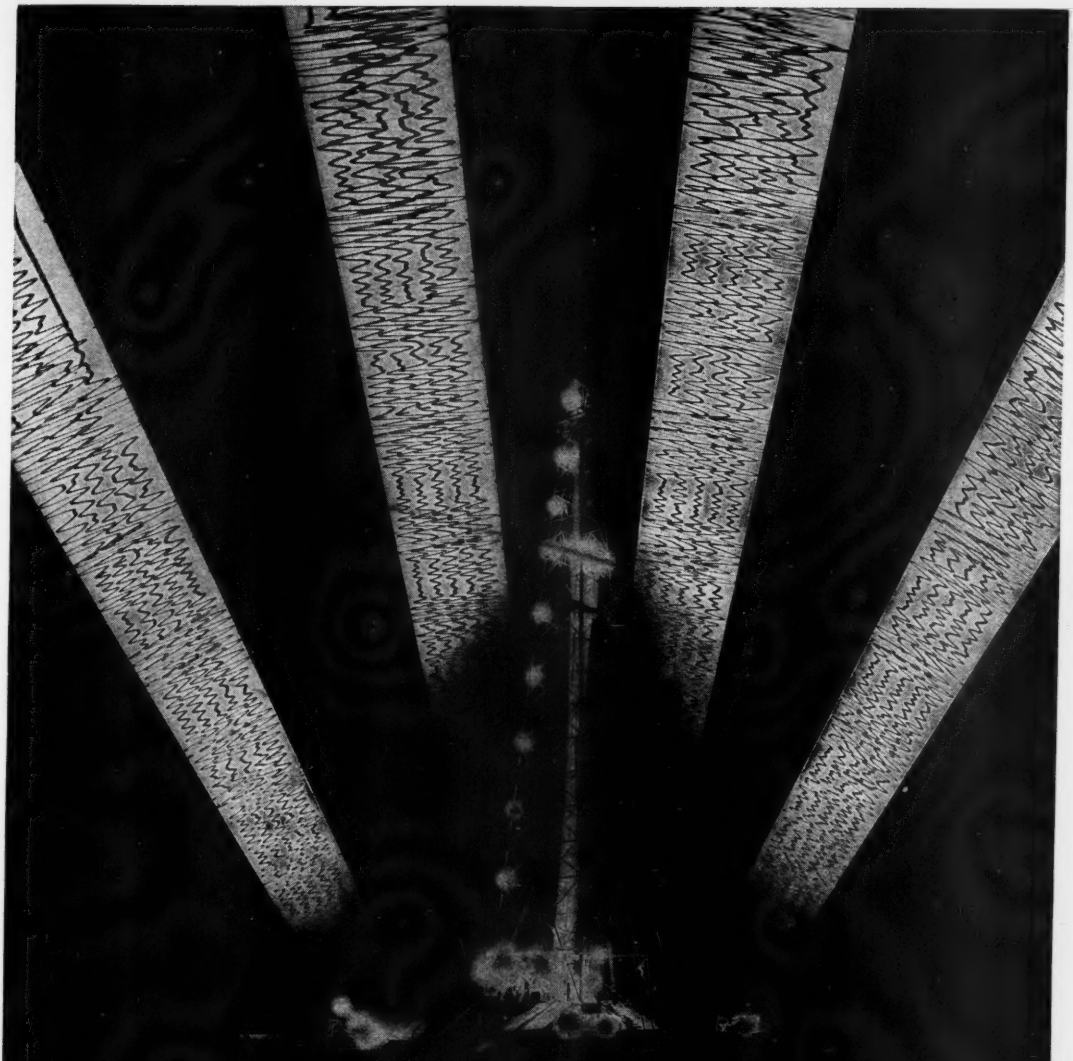

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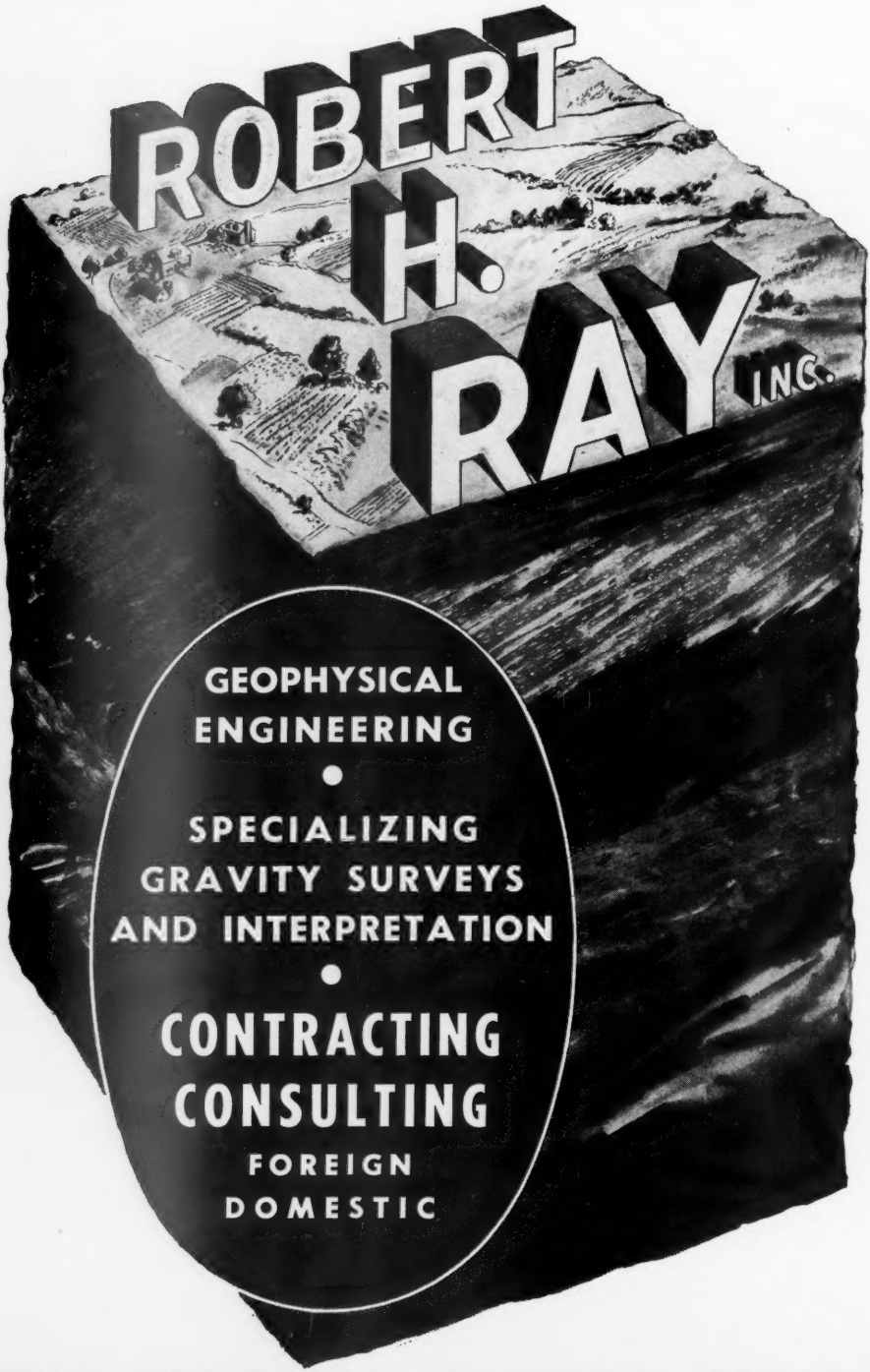
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by

Members of the staffs of the Departments of Geology, Geophysics, and Petroleum Engineering of the Colorado School of Mines, under the direction of F. M. Van Tuyl

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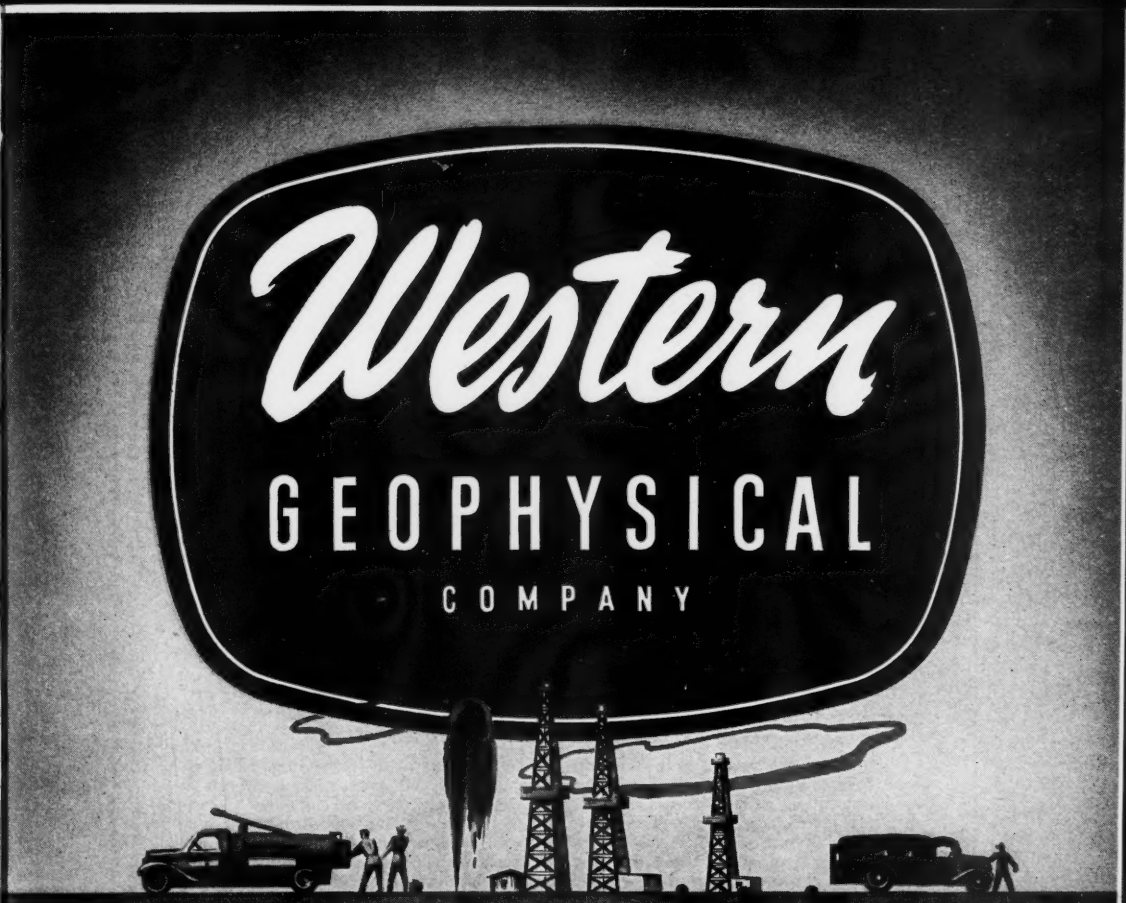

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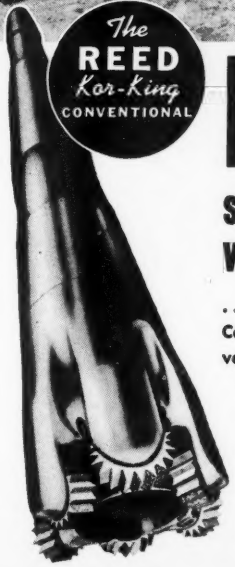

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